SOME CORRELATIONS IN THE COST OF MILK PRODUCTION*

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INTRODUCTION

This study represents an attempt to discover some of the correlations existing among the different factors in the business of dairying, and especially to trace out the effects of the various factors on the production and the cost of production of milk. The statistics on which the study is based were originally collected and used for an investigation of "The Relation of Size of Dairy to Economy of Milk Production."[1] This study was made while the writer was a student at Delaware College. The statistics were collected by personal visits to eighty-seven dairies in northern Delaware and southeastern Pennsylvania, a section in which fairly uniform conditions prevail as to markets, climate, topography, type of soil, and types of farming in general use.

Representative dairies were visited and such information as dairymen were able to give was obtained. These data were supplemented by observations, and a rather exhaustive series of questions, cross questions, and check questions was used in an attempt to analyze each business and to resolve it into the component factors of investment, expenditure, and income. The estimates of the dairymen often appeared far from accurate, even in the case of large dairies which were usually supposed to be operating under the most up-to-date systems of farm accounting. A sufficient uniformity, however, prevails in the data from farms operating under similar systems of management, to indicate that the averages of several dairies will be nearly, if not quite, accurate.

It has been very tritely remarked that: "The great pity is not that we are so ignorant of cosmic forces, but that we know

*This paper is concluded in next issue—EDITOR IN CHIEF.

[1]Delaware Bulletin No. 118, Delaware College Experiment Sta.

so many things that are not true."[2] The writer has borne this consideration in mind throughout the study and has tried to maintain a wholesome skepticism, and to examine critically even the most generally accepted theories of scientific principle where this could be done and has tried to be doubly skeptical of his own conclusions in this study.

Method of Computation

For convenience and simplicity, the following rules for the computation of the factors in expense have been applied:

1. *Interest* on investment is reckoned at 5 per cent.

2. *Value per cow* is reckoned on the basis of the value of *grade cows* of similar type and productiveness in the same neighborhood. The writer has proceeded on the hypothesis that interest and depreciation on the additional value of pure bred cows, inherent in the fact of their registry as pure breds, is offset by the corresponding value of their offspring.

3. *Depreciation* on cow is reckoned at 20 per cent, on bull at 12 per cent and is taken as covering depreciation on value of cow or bull, due to the length of their respective periods of usefulness, and insurance on life of the animal.

4. *Pasturage.* In estimating the cost of pasturage, the usual rate of pasturage hire in the neighborhood in which a particular farm was located was used as a basis for computation.

5. *Cost of grains and forage.* Dairies were charged with grains and forage produced and consumed on the farm at the farm value in the neighborhood; that is, the market value minus cost of delivery. Grain, forage and other feed, which was purchased, were, of course, charged against the dairy at cost.

6. *Labor.* In each dairy, an estimate of the amount of time spent per day on the dairy during the different seasons of the year as, in winter, the pasturage season, etc., was obtained and was charged to the dairy at the rate paid for labor during the year plus cost of board, where laborers were boarded at the expense of the farmer.

[2] Williams, an American Town.

7. *Cost of management.* In the case of this factor, so difficult to compute with any degree of accuracy, the farmer's estimate of the value of his own time per hour has been used as a basis. Where the farmer performs actual work in the dairy, as in small dairies, "Labor" is charged with the number of hours of actual work at the rate which the farmer pays his men. The difference between this and the farmer's estimate of his own value is charged to "Management." In large dairies where a manager is employed, this difficulty does not occur.

8. *Credit for manure.* Cows are credited with the amount of manure they produce, at the rate of one dollar per ton, arbitrarily adopted.

9. *Credit for calf.* Each dairy is credited with the number of live calves dropped in it, at their value at birth, usually four or five dollars. In order to be consistent with rule 2, pure bred calves are valued at the same rate as grades of corresponding size, conformation, and vigor.

10. *Total expense per cow* is computed by adding together all the factors in expense.

11. *Total income per cow* has been calculated by adding together all factors in income, as income from milk and butter, and credits from calf and manure.

12. *Profit per cow* is obtained by subtracting total expense from total income.

13. *Cost per quart* is reckoned by subtracting credits due to calf and manure from total expense, thus getting net expense of milk, which is then divided by the number of quarts per cow per year.

14. *All data* are for the year 1916.

Section I. The Correlation of Labor to Other Factors in Milk Production

1. Adaptation of data

To adapt the data collected for a study of "The Relation of Size of Dairy to Economy of Milk Production" to a study of "The Correlation of Labor to Other Factors in Milk Produc-

tion" required something more than a simple division into classes on the basis of the amount of labor used. In the first place, it was found in the former study that the amount of labor required in a given dairy was to some measure dependent on the size of the dairy, and that dairies of more than 20 cows were able to use labor to a greater advantage than the ones of smaller size. Hence it would be unfair to compare the dairies of fewer than 20 cows with the larger ones. Again the dairies of over 40 cows are usually managed under a system different from those of fewer than 40. Hence the dairies of over 40 cows should not be compared directly with the smaller ones. The data was, therefore, first divided into three parts on the basis of size. Dairies of fewer than 20 cows comprising the first, dairies of more than 20 and fewer than 40 the second, and those of 40 or more the third part.

Division of dairies into classes

CLASS NUMBER*	NUMBER OF DAIRIES	SIZE OF DAIRIES	NUMBER OF HOURS OF LABOR PER COW PER YEAR	PRODUCT SOLD AS
10	7	Under 20 cows		
11	9	20 to 39 cows	Under 140	
12	8	40 or more cows		
13	11	Under 20 cows		
14	10	20 to 39 cows	140 to 200	Market milk
15	5	40 or more cows		
16	3	Under 20 cows		
17	2	20 to 39 cows	Over 200	
18	3	40 or more cows		
19	4	All but 2 of under 20	Under 140	
20	4	cows	140 to 200	Butter
21	4		Over 200	
22	4	All of more than 20	Under 140	"A" milk and "nur-
23	3	cows	140 to 200	sery" milk
24	4		Over 200	
25	3	80 or more cows	Over 200	"Certified" milk

* The numbering of classes proceeds from the first part of the study published in the Delaware Bulletin, No. 118, and is consecutive throughout the entire study.

TABLE 1

Section I. Correlation of labor to some other factors in the production of milk

CLASS	NUMBER OF DAIRIES	NUMBER OF HOURS OF LABOR	COST OF LABOR	COST PER HOUR	AVERAGE NUMBER OF COWS	OTHER ANIMALS UNITS—RATIO	NUMBER OF ACRES PER COW	INVESTMENT IN BUILDINGS	INVESTMENT IN EQUIPMENT	INVESTMENT IN COW	NUMBER OF QUARTS MILK PER YEAR	INCOME FROM MILK	CREDIT FROM CALF AND MANURE	TOTAL EXPENSE	TOTAL INCOME	PROFIT OR LOSS	COST PER QUART	PRICE PER QUART	PROFIT OR LOSS PER QUART	PERCENT OF TOTAL EXPENSE SPENT FOR LABOR	NUMBER OF TENANTS	NUMBER OF OWNERS
Summary of classes producing market milk																						
10	7	119	$16.52	$0.139	13.0	1.2	8.9	$116.66	$12.20	$73.57	2,106	$ 89.37	$12.19	$142.86	$101.70	−$41.17	$0.070	$0.044	−$0.026	11.7	1	6
11	9	119	17.35	0.145	25.0	0.6	5.9	144.55	12.58	78.33	2,567	113.39	14.13	148.42	127.47	−20.96	0.055	0.045	−0.010	11.7	1	8
12	8	111	17.67	0.159	56.5	0.4	4.2	106.91	9.81	87.25	2,794	125.25	14.38	143.78	139.26	− 4.27	0.048	0.043	−0.005	12.3	0	8
13	11	156	21.30	0.137	13.8	1.2	12.4	114.30	7.90	73.18	2,112	95.24	13.78	148.16	109.94	−38.21	0.068	0.046	−0.022	14.4	3	8
14	10	163	25.22	0.155	30.9	0.6	5.6	103.38	11.99	86.50	2,817	141.14	14.63	159.31	155.77	− 3.54	0.054	0.053	−0.002	16.6	3	7
15	5	180	29.51	0.164	51.8	0.6	5.5	122.29	16.21	90.00	3,090	132.20	13.92	158.43	146.17	−16.24	0.047	0.043	−0.004	18.6	0	5
16	3	279	41.06	0.147	14.0	0.7	6.8	246.65	4.67	78.33	2,462	122.12	13.69	205.66	135.81	−69.85	0.079	0.048	−0.031	19.9	1	2
*17	2	265	41.55	0.157	22.5	0.4	9.0	119.00	7.75	72.50	2,798	99.20	14.50	196.09	123.70	−72.39	0.064	0.039	−0.025	21.2	0	2
18	3	248	35.62	0.144	55.6	0.5	5.5	87.36	10.72	88.33	3,477	178.31	14.30	189.81	226.24	+36.43	0.052	0.062	+0.010	18.7	0	3
Summary of classes producing butter																						
19	4	124	16.14	0.130	12.0	1.2	12.4	138.11	13.00	66.25	1,717	84.93	13.57	129.75	98.48	−31.27	0.076	0.051	−0.025	12.4	4	0
20	4	169	25.25	0.137	11.0	1.3	11.5	161.88	18.10	75.00	1,457	98.29	16.31	181.97	119.60	−62.38	0.104	0.053	−0.051	13.8	0	4
21	4	266	37.29	0.144	11.2	1.2	12.5	153.33	21.25	73.75	2,133	113.60	15.41	162.08	129.02	−33.06	0.075	0.053	−0.017	23.0	0	4
Summary of classes of producing "A," "nursery" and "certified" milk																						
22	4	118	19.18	0.163	29.5	0.5	5.0	113.45	10.30	91.25	2,983	180.16	13.22	158.58	194.73	+36.15	0.052	0.065	+0.013	12.1	0	4
23	3	183	30.21	0.165	52.0	0.7	6.0	82.74	19.47	91.66	2,775	168.03	12.93	175.75	180.89	+ 5.14	0.058	0.061	+0.003	17.2	0	3
24	4	320	63.66	0.198	49.5	0.5	6.7	311.34	17.72	97.50	3,726	237.89	14.43	250.51	256.07	+ 5.56	0.066	0.067	+0.001	25.4	0	4
25	3	294	58.97	0.201	86.6	0.5	4.8	192.33	22.93	95.00	3,254	324.60	16.17	244.50	340.77	+96.27	0.071	0.101	+0.030	24.1	0	3

* Only two herds in this class.

Neither would it be fair to compare dairies producing different products, to compare dairies producing market milk with those producing "certified" milk, or butter-making dairies with those producing "A" milk or "nursery" milk. This necessitated a further division into four groups, as follows:

1. Dairies producing market milk.
2. Butter making dairies.
3. Dairies producing "A" milk or "nursery" milk.
4. Dairies producing "certified" milk.

The above table may serve to make more lucid the final division into classes.

Peculiarities of the various classes

Classes 10, 13, and 16. These classes were composed of smal dairies, which were usually conducted as side lines on farms of varying size. At the lower extreme in this group are to be found the family cows in small herds of 5 to 10 cows. These usually received a large amount of individual attention, being considered, often more as pets than as economic producers.

The dairies of from 10 to 20 cows take on a different aspect. They were commonly conducted as business propositions in an unbusinesslike manner. That is, they were looked on as a source of income, but were not usually the main source, and therefore seldom received a sufficient amount of labor or thought, especially of the latter, to bring them to the point of maximum productivity.

The investment in buildings, in this group, commonly ran high, except in a few cases where the shelter provided was insufficient.

It may be said here that, many of the farmers in this neighborhood, especially those keeping small dairies find themselves saddled at the beginning with buildings erected for an age now past. The barns are strongly built often of stone, and have stood and will continue to stand for a great many years. But they are frequently unsuited to the farmer's present needs, being often too big, on the small farms, and almost always dark

and unsanitary, and at the same time represent large investments, which strongly discourage the desirable tendency to remodel or replace them. This complicates the study as far as buildings are concerned by introducing large amounts of fixed capital which cannot be liquidated, and which by their very fixity, militate against progress in the direction of convenience and sanitation.

Classes 11, 14, and 17. The dairies in these classes were conducted along more businesslike lines than the smaller ones. Their size in itself rendered this more easy. The cows were generally of better types, with greater productive capacity. They were fed and cared for with more intelligence. Labor was used to better advantage, and the farmer becomes in these classes more of a manager and less of a laborer than in the smaller dairies.

These dairies were commonly the main, though not the only, source of income on the farms where they were kept.

Classes 12, 15, and 18. These classes are composed of dairies which were the main sources of income on the farms where they were kept. Indeed, in these classes the rest of the farm was usually run as an adjunct to the dairy rather than the dairy as an adjunct to the farm.

Paid managers were often employed, or where the owner managed the dairy, he usually did but little labor, strictly speaking. The buildings were usually built to fit the dairy rather than the dairy to fit the buildings. The cows were intelligently fed and cared for and were carefully selected.

Classes 19, 20, and 21. The butter-making dairies were, with two exceptions, dairies of fewer than 20 cows. The product was often disposed of as butter rather than as milk, because the small size of the dairies made the cost of hauling milk to the shipping station every day, prohibitive. The comment on classes 10, 13, and 16 in regard to the makeup of the dairies applies to those in this class with even more force, since they occupied a subordinate position on the farms where they were found and too little thought and care was given them. The

cows were of the poorest types found and were usually in the poorest condition.

These establishments were usually quite unprofitable. One, however, class 39, is being conducted at a profit, for it is intelligently managed and supplies a special demand for fancy butter.

Classes 22, 23, and 24. This group is composed of large dairies which are engaged in the production of the higher grades of milk, as "A" milk and "nursery" milk. The buildings are as a rule both economically and durably constructed, their interiors well kept, well lighted and well ventilated, and their surroundings clean. The cows are carefully selected and of highly productive types. The herds are intelligently managed and fed. A greater outlay in labor and capital is required in these classes in order to produce the higher grades of milk referred to above. The higher prices received, however, provide a sufficient recompense for this additional expenditure.

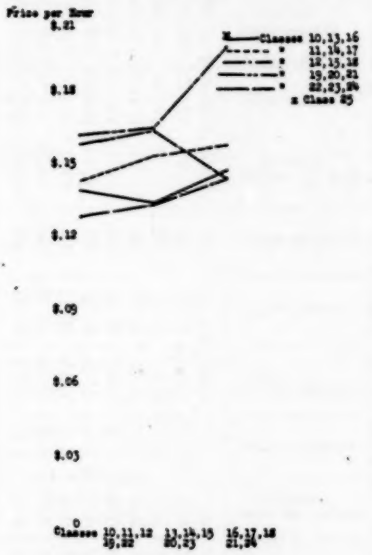
In this group three of the "Millionaire's" type of dairies appear—dairies Nos. 12, 38, and 46. These are operated more as a hobby by rich owners than for business purposes. They are characterized by unnecessarily large investments in buildings and equipment, which in dairy No. 12 reach the absurdly high figure of $900 per cow. They produce, however, a high grade of product, and by selling at top-notch prices, are able, strangely enough, to hold their own against more businesslike dairies.

Class 25. Class 25 is composed of 3 dairies which produce certified milk and consequently cannot well be compared with any other class, because of the high cost and high selling price of their product, and the large amount of labor required. All three are big dairies, composed of the finest type of cattle, mostly pure breds. They are run by experienced and well paid managers and by businesslike methods and, because of the high price at which certified milk is sold, it will be evident that two of them are conducted at a substantial profit, while the third is "breaking even."

2. RELATIONSHIP OF LABOR AND OTHER FACTORS IN MILK PRODUCTION

Cost of labor per hour

The average cost per hour of labor in dairies using less than 140 hours per cow per year is $0.147, in dairies using from 140 to 200 hours per cow per year it is $0.152, and in those using



GRAPH I. PRICE PAID PER HOUR FOR LABOR

over 200 hours of labor, it is $0.158. This is illustrated by graph I, which shows also that there is a strong tendency for the dairies using the most labor to pay it most highly. There is, further, a tendency for the dairies making the highest profits or lowest losses to pay higher wages than those which are less profitable. This, however, is not so apparent where individual dairies are examined, but becomes obvious only as a general tendency where a large number of dairies are taken into consideration.

TABLE 2

Section II. Correlations of concentrates to other factors in milk production. Averages of classes 26 to 34

CLASS NUMBER	NUMBER OF HERDS IN CLASS	NUMBER OF COWS IN HERDS	VALUE PER COW	MONTHS OF PASTURAGE	TONS OF SILAGE	TONS OF SILAGE AND ROOTS	TONS OF FORAGE	POUNDS OF GRAIN FED	COST OF GRAIN	HOURS OF LABOR	QUARTS OF MILK PER YEAR	TOTAL EXPENSE	TOTAL INCOME	COST PER QUART	PRICE RECEIVED PER QUART	PROFIT OR LOSS PER QUART	RATIO OF CONCENTRATES TO MILK PRODUCED*
26	15	11.0	$71.33	6.0	2.0	0.1	3.4	1,627	$25.84	163	1,901	$132.98	$ 98.26	$0.075	$0.046	−$0.029	2.54
27	10	27.1	76.00	5.2	3.7	0.2	2.4	1,663	27.92	145	2,571	140.38	136.47	0.055	0.051	−0.004	3.35
28	8	48.9	83.77	5.9	4.5	0.2	1.3	1,517	22.81	165	2,729	149.97	146.16	0.049	0.048	−0.001	3.89
29	7	12.4	73.57	6.2	2.5	0.3	2.2	2,241	32.19	142	2,136	155.09	114.79	0.075	0.044	−0.031	2.07
30	11	27.0	76.72	5.7	3.2	0.002	1.8	2,278	35.38	148	2,380	148.32	148.29	0.059	0.058	−0.001	2.27
31	10	72.2	89.50	5.2	6.2	0.5	1.5	2,509	35.50	209	3,450	190.30	233.70	0.052	0.065	+0.013	2.99
32	9	12.6	75.00	6.2	3.2	0.5	2.3	3,699	50.11	205	2,317	173.62	135.20	0.075	0.050	−0.025	1.36
33	9	26.3	92.55	5.8	3.5	0.6	1.6	3,894	53.58	184	3,006	173.06	164.63	0.058	0.050	−0.008	1.66
34	7	66.4	92.14	4.3	6.6	0.5	1.5	3,784	52.11	200	3,196	197.71	192.45	0.060	0.055	−0.005	1.84

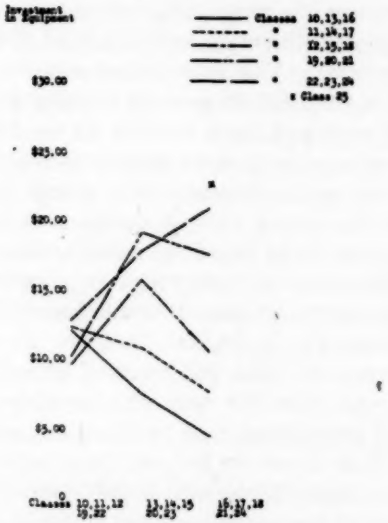
* The total weight of concentrates fed per cow being taken as one.

Investments in buildings

No correlation seems to exist between investment in buildings and the amount of labor used. Though a wide variation was evident, it did not apparently follow any definite rule. This is probably because the majority of the buildings are older than the accompanying systems of management, as referred to above.

Investment in equipment

In the relationship of labor to the amount of equipment used, a condition appears which may at first seem rather extraordinary.



GRAPH II. INVESTMENT IN EQUIPMENT

It will be seen in graph II that as more labor is added, the investment in equipment also increases at first, but later is reduced as still more labor is used. This condition obtains in all classes except those of fewer than 20 cows and in the classes producing butter.

In the dairies of fewer than 20 cows, which produce market milk, very little more equipment is needed for a dairy of 15 cows than for one of 7 or 8, since the work in such dairies is nearly always done by two persons—the farmer and one hired man, or rarely two. The usual equipment is such dairies is very simple. That used for handling the milk generally consists of 2 or 3 buckets, 1 strainer, and 6 or 8 milk cans, and except for the number of milk cans which may increase slightly, the milk of 15 cows may be handled as well with this equipment as that of 7 or 8. The same holds true of most of the other equipment used in such a dairy. Hence, the first irregularity in graph II is explainable and is to be expected.

In the latter case the irregularity centers about class 21 which has an average investment in equipment of $21.25, the highest average of any class. This may be accounted for by the investment in equipment of $30.00 per cow in dairy no. 4. This dairy was originally equipped for a herd of 12 or 14 cows and was subsequently reduced to 5 cows, greatly increasing the overhead charges per cow for equipment. The charge for buildings was kept down by the use of part of the barn for other live stock, but the equipment could be put to no other use. If the investment in equipment in this dairy had been reckoned on a basis of 12 cows, the curve for class 21 would have followed the same trend as in classes 16, 17, 18, and 24.

In dairies using less than 140 hours of labor per cow per year the care bestowed upon the cows was insufficient, as is reflected by the cost of production, and the farmers are not sufficiently interested in their dairies to provide them with complete equip ment. In the dairies using 140 to 200 hours of labor per cow per year, both the greater amount of labor and the greater amount of equipment may be accounted for to a considerable degree by the greater interest taken by the dairymen in their cows. Thus, up to this point no fixed rule of cause or effect appears to exist, but both are affected by a third factor, the interest of the dairymen in their cows. Beyond this point, however, where more labor is supplied less equipment is needed, or conversely where less equipment is kept more labor is required.

It will readily be seen that there are both absolute and relative requirements for labor and for equipment. Until the absolute requirements for both have been satisfied, an increase in one cannot replace a portion of the other. In the dairies covered by this study, it is evident that the absolute requirement for labor is not usually satisfied by less than 140 hours per cow per year, and therefore the addition of more labor in dairies where less than this amount is used, will not operate to reduce the requirement for equipment.

Credit from calf and manure

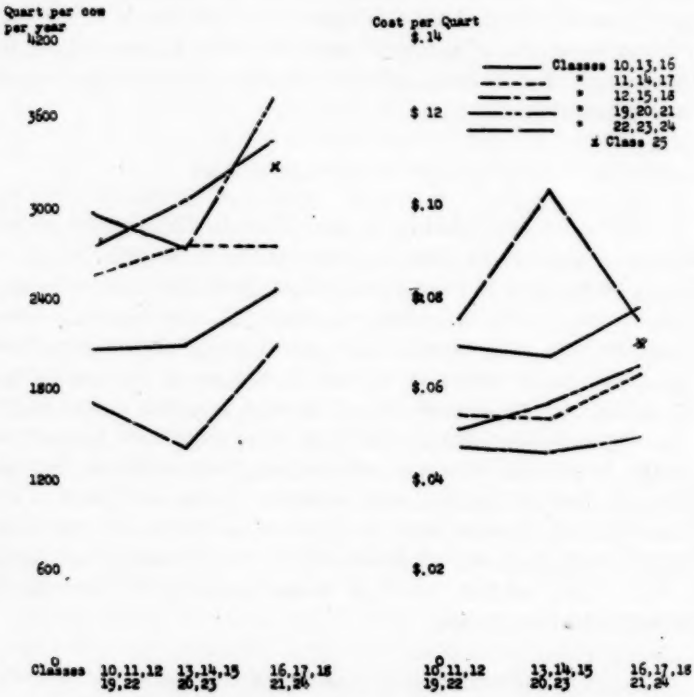
It will be observed that in all the different divisions of dairies, there is a general though irregular tendency for this factor to rise as more labor is added, indicating, first, that more attention to the cows resulted in a larger number of more vigorous calves being dropped; and second, that a result of the use of more labor was the saving of a greater amount of manure or conversely that the saving of a greater amount of manure required more labor.

In many dairies the production of as large an amount of manure as possible was a conscious aim, but in others this was more or less incidental and without conscious effort. The irregularity of the data and their refusal to follow a more clearly defined trend may be attributed to the small number of dairies in each class among which a wide variation in systems of management was found.

Production and cost of production

An examination of the column headed "Number of quarts per year" will show an increase from an average of 2489 quarts per cow per year in classes 10, 11, and 12, using an average of 116 hours of labor per cow per year to 2673 quarts in classes 13, 14, and 15, using an average of 166 hours per cow per year, and to 2912 quarts in classes 16, 17, and 18, using an average of 264 hours per cow per year. The same general trend is shown in the classes producing butter and in those producing the better

grades of milk, and the variations from this tendency in classes 20 and 23 may be ascribed to the small number of dairies in these classes coupled with the occurrence in them of dairies of low productive capacity.



GRAPH III. PRODUCTION AND COST PER QUART

This is significant, especially when one considers that there is no corresponding increase in the intrinsic value of the cows comprising the dairies, indicating as it does that each intelligently added unit of labor and care may be expected to produce an increase in the production of the dairy. It is also noteworthy, that the addition of 50 hours of labor to that used in the first three classes produces an increment of 184 quarts of milk,

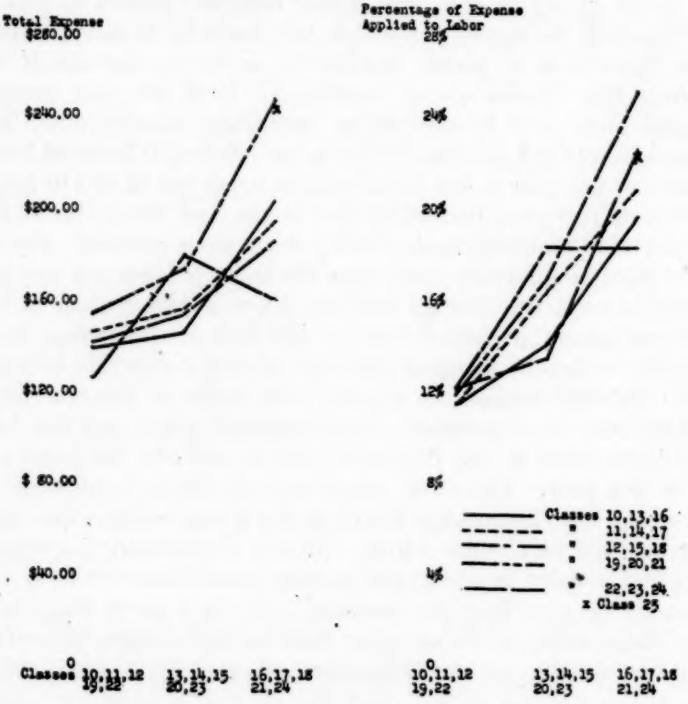
while a further addition of 98 hours of labor produces an increase of only 239 quarts. And this is what might be expected in view of the natural law limiting the productivity of the cows. This law is the well known one providing that the farther a cow is forced above her natural productivity, the more difficult will it be to secure each farther increase.

If the above be true, one should naturally expect to find it reflected in the cost of production, nor would he be disappointed, for there it is as plainly evident as in the production, if we except the classes above mentioned. It is of even greater significance that in the classes producing market milk, the average cost per quart in dairies using 140 to 200 hours of labor per cow per year is less than in those using less than 140 hours per cow per year, indicating that in the first three classes the point of diminishing returns has not yet been reached. But in the third group where more than 200 hours of labor per cow per year is used, the average cost per quart is higher than in the second group. Hence, it may be said that in the *average* dairy in this study, the marginal point for labor is somewhere between 140 and 200 hours. An attempt was made to discover more closely the exact location of the marginal point, and the data indicated that it was probably between 180 and 200 hours per cow per year. The data, however, were found insufficient to warrant this statement as anything but a suggestion, which may or may not be of some value. Since it is practically impossible to find a dairy in which the average conditions obtain, it will readily be seen that the marginal point in a given dairy may be considerably above or below that for the average, depending on size of dairy, system of management, capacity of cows, etc.

The proportion of expense applied to labor

A glance at the column "Total expense" will show that there is a tendency for expense to increase somewhat more than twice as fast as could be accounted for by the expense of the additional labor alone, and that this tendency becomes more pronounced as more labor is used. Sufficient data to analyze this informa-

tion completely is not at hand. It may, however, be seen to accompany a general increase in all expenses rather than of any particular set. In other words it was incident to an attempt to force the production of the dairies above the average by the use of more, and more expensive feeds and greater care throughout in the operation of these dairies.



GRAPH IV. TOTAL EXPENSE AND PROPORTION OF TOTAL EXPENSE APPLIED TO LABOR

Graph IV will show that, though the greater part of this increase is due to other factors than labor, labor increases more rapidly in proportion than the other factors. The proportion which the cost of labor represents to the total expenses rises from 11.9 per cent in classes 10, 11, and 12, to 16.5 per cent in

classes 13, 14, and 15, and to 23.2 per cent in classes 16, 17, and 18. This increase in ratio makes the foregoing comparisons legitimate and valid. These comparisons would have been of practically no value, had the increase in the cost of labor from class to class been accompanied by a *proportionate* increase in each other factor. To make a fair comparison, it is necessary that one factor be variable, while the others remain constant, or if this condition can not be obtained, it is at times legitimate to compare a variable factor with others which do not change so rapidly, provided the changes in the variable are not wholly incident to changes in the factors treated as constants. The latter is the condition of this study.

SUMMARY

It cannot be said that the labor used in each dairy where less than 140 hours was spent per year on each cow was positively insufficient, for in several cases farmers were enabled by efficient organization of their dairies to get along very satisfactorily with much less than this. It should be borne in mind therefore that the following conclusions apply only to the averages of the dairies included in this study.

1. Up to an average of 168 hours of labor per cow per year, a state of increasing returns was found to exist. That is, each unit of labor applied up to this point resulted in an increase in product greater than the preceding unit.

2. After an average of 166 hours of labor per cow per year was passed, a state of decreasing returns was observed.

3. Dairies using 140 to 200 hours of labor per cow per year have a larger investment per cow in equipment than those using under 140 hours or over 200 hours of labor.

4. The dairies using the most labor pay the highest price for it.

5. On an average, milk is produced at a lower cost per quart in dairies using from 140 to 200 hours of labor per cow per year, than in those using either more or less.

6. The dairies using larger amounts of labor per cow had more live, vigorous calves dropped in them than those using less, and were able to save more manure.

7. Where more labor was used, it was found that other expenses increased coincidentally, but not so rapidly, in proportion as the expense of labor.

Section II. The Relation of the Amount of Concentrates Used to Other Factors

1. Adaption of data

For this phase of the study, it was again necessary to reclassify and regroup, and to some extent to retabulate the data at hand. The principles, under which the regrouping was done, were, however, simpler than those adopted in section I. It was not necessary to divide the data on the basis of distribution of product, as this had no direct bearing on the amounts of grain fed, and further the dairies producing products other than market milk are so generally distributed that they counterbalance in the different classes. The butter producing classes are, with two exceptions, all to be found in the three classes of fewer than 20 cows, while the dairies producing the higher grades of milk are distributed promiscuously through the 6 classes of larger dairies.

Division into classes in section II

CLASS NUMBER	NUMBER OF DAIRIES	SIZE OF DAIRIES	NUMBER OF POUNDS OF CONCENTRATES FED PER COW PER YEAR
26	15	Fewer than 20 cows	Less than 2,000
27	10	20 to 39 cows	
28	8	40 or more cows	
29	7	Fewer than 20 cows	2,000 to 2,999
30	11	20 to 39 cows	
31	10	40 or more cows	
32	9	Fewer than 20 cows	3,000 or more
33	9	20 to 39 cows	
34	7	40 or more cows	

The division from the standpoint of size was preserved as in section I, and each of these divisions was divided on the basis of quantity of concentrates used. The above table will illustrate the method of division. This arrangement gives nine classes, none of which contains fewer than seven dairies, making a sufficiently small number of classes for convenient comparison and having in each class a sufficient number of dairies to make the average of the classes comparable and to tend to remove differences between classes arising from variations in individual dairies.

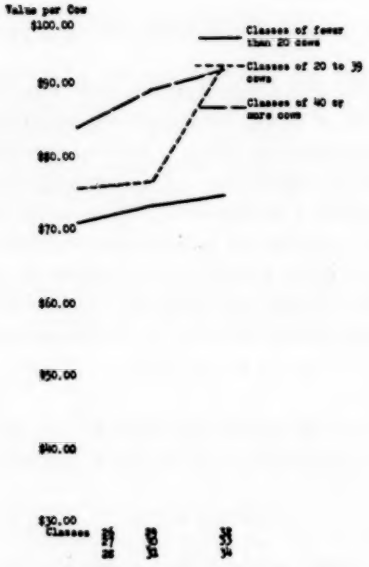
2. CORRELATIONS BETWEEN THE AMOUNT OF CONCENTRATES FED AND OTHER FACTORS IN MILK PRODUCTION

Value of cows

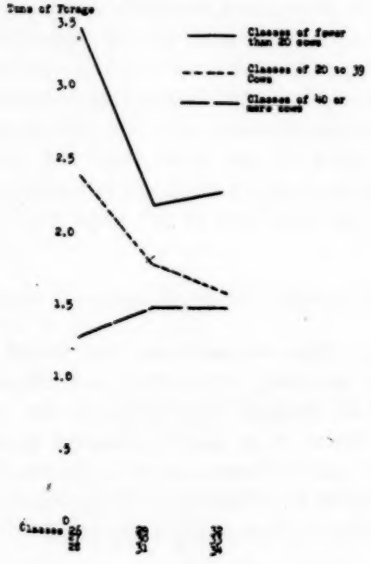
It will be seen from graph V that there is a constant though uneven tendency for the value per cow to rise, as more grain is fed, and also that there is a tendency for the larger dairies to be composed of more valuable cows than the smaller ones. This latter tendency is due partly or mostly to the greater productive capacity of the cows in the larger dairies. But within each of the three divisions as to size, it is not possible to tell how far the greater value of the cows receiving the most feed is due to their capacity to make good use of more feed, and to what extent to the better condition of the cows from the use of more feed.

Pasturage, silage, soilage, and roots

There was but little variation in the extent to which pasturage was used, and such correlation as existed cannot be said to follow any well defined correlation to the amount of concentrates fed. There is a slight increase in the amount of silage fed as the use of concentrates is increased. No definite relationship seems to exist between the amount of grain fed and the extent to which soilage or roots are used.



GRAPH V. VALUE PER COW



GRAPH VI. TONS OF FORAGE FED PER COW

Forage

It will be seen from graph VI that there is a general tendency for the amount of roughage used to decrease as the quantity of concentrates is increased. This is what might be expected; but the sudden drop from 3.4 tons of forage in class 26 to 2.2 tons in class 29 could not be explained by the increase in the use of concentrates from an average of 1627 pounds in class 26 to an average of 2241 pounds in class 29, and to explain this discrepancy, it is necessary to examine the data carefully.

It will be observed that most of the herds in class 26 use unnecessarily large amounts of roughage. This is composed mostly of corn stover which is thrown to the cattle, on these farms, in much greater quantities than they could possibly eat. Many of these dairies, which are among the smaller ones, are kept on large farms growing corn as their principal crop. The dairies are kept as a side industry, partly for the purpose of trampling the corn stover and converting it into manure, so that it may be returned to the soil as a fertilizer. Since it is not possible to tell just how much of this stover was eaten and how much more was wasted by trampling, this discrepancy cannot be removed.

The whole trouble was that the farms on which these dairies were found, were understocked; on most of them a great many more cattle, sheep, or other animals, could have been maintained without additional expense for roughage.

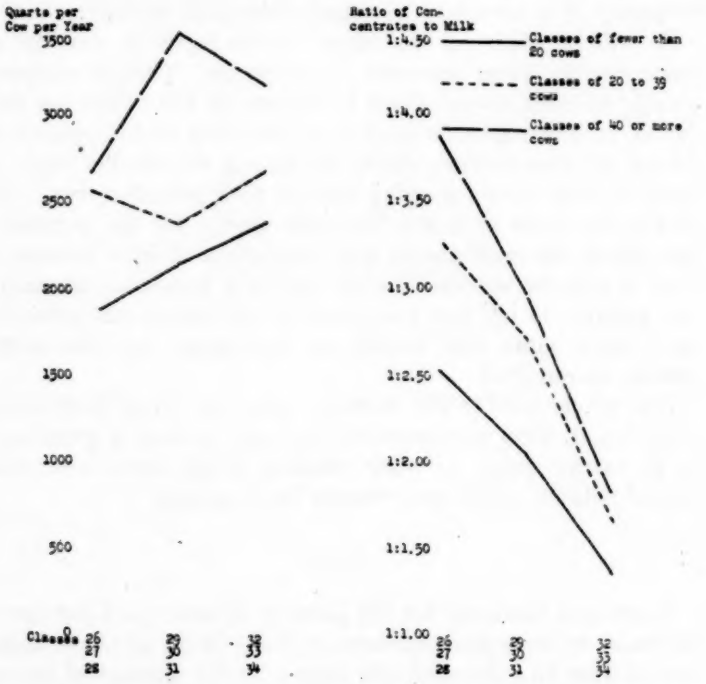
Labor

There is a tendency for the amount of labor used per cow to increase, as more concentrates are fed. Both of these factors are affected to a considerable degree by the amount of interest taken by the dairyman in his cows. If the dairyman is deeply interested in his herd, or if the dairy contributes the larger part of his income, he may be expected to bestow more care on it and feed more heavily. This probably explains also the correlation between the amount of silage and of concentrates

fed. Thus, none of these three factors stand in a causative relationship to either of the others but all are affected by the fourth factor, the interest of the dairyman.

Correlations of concentrates to production

From graph VII it may be observed that there is a correlation, though not a regular one between the amount of grain used and the production per cow.



GRAPH VII. PRODUCTION PER COW AND RATIO OF CONCENTRATES TO MILK PRODUCED

The second part of graph VII illustrates the condition of diminishing returns which stands out strikingly in this part of the study.

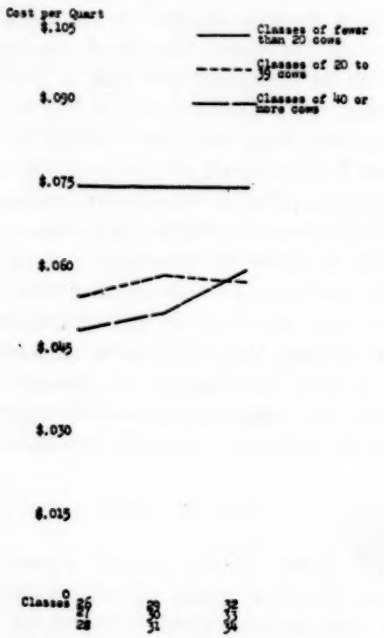
Taking the amount of concentrates fed as 1, the ratio of concentrates fed, to the amount of milk produced, decreases from 1:2.52 in class 26 to 1:1.36 in class 32, from 1:3.35 in class 27 to 1:1.66 in class 33, and from 1:3.89 in class 28 to 1:1.84 in class 34. In short, the more concentrates are used, the less milk will be produced per unit of feed, through there may and probably will be an increase in the total production.

It will be observed that the three curves in the second part of graph VII are farther apart at first and converge as more and more grain is added. This is significant, indicating that in the larger dairies where greater intelligence in management is usually found, more milk is generally produced per unit of feed, when but little feed is used, than in the smaller ones where feeding is less intelligently done and is more indiscriminate. But as more concentrates are added, this differential advantage of the large dairies, resulting from intelligence of management, is rapidly lost, and the large and small dairies tend to approach a standard ratio between feed consumed and milk produced.

Cost per quart

In graph VIII there will be noticed a general but irregular tendency for the cost per quart of milk to rise somewhat, as the amount of concentrates used is increased. But that this does not hold is shown by the figure for the dairies of fewer than 20 cows, in all three classes of which the average cost per quart is exactly the same. This is probably to be explained by the better care and greater interest in their dairies among the farmers in classes 29 and 32 over those in class 26. It has been suggested above that the amount of feed used depends somewhat on the intelligence of the farmer and his interest in his dairy. Hence, this greater care might be expected to reduce the cost per quart in classes 29 and 32 from what it would otherwise be, especially since the widest variation in interest and intelligence in management is to be found among the smallest dairies. If it were not for this complication the curve for the

dairies of fewer than 20 cows would probably run parallel to those for the larger dairies.



GRAPH VIII. COST PER QUART OF MILK

SUMMARY

1. The value of the cows was seen to rise as the amount of concentrates used was increased. This was due partly to the better condition of the cows resulting from heavier feeding, and partly to a difference in their productive capacity.

2. Slightly more silage was fed per cow as the amount of grain fed was increased.

3. The amount of forage used decreased as the use of concentrates increased. In the smaller dairies this was partly due

to more intelligent use of roughage in the dairies using the larger amounts of concentrates.

4. Slightly more labor was used in dairies in which large amounts of grain was fed.

5. The production per cow increased as more concentrates were fed, but:

6. An inverse correlation exists between the amount of concentrates used and the production of milk per unit of grain. Large dairies are able to produce more milk per unit of grain than the small ones, where only a small amount of grain is used, but as more grain is fed, this advantage is lost.

7. The cost per quart of milk tends to increase slightly as more concentrates are used.

Section III. The Correlation of the Proportion of Concentrates Purchased to the Cost of Milk Production

1. Adaptation of data

The tabulation and classification of data were done in this section under the same principles as in section II. The dairies were first divided into three groups according to size as in sections I and II. These groups were then subdivided according to the proportion of concentrates purchased and fed per cow to the total amount of concentrates fed per cow. Percentage was used as a measure of proportion and the dairies were so grouped that each of these groups would contain approximately equal numbers of dairies. Thus the second contains dairies which purchase about the average proportion of their grains, the first contains those purchasing less, and the third those purchasing more than the mean amount.

The following table will illustrate the method of division:

Division of dairies into classes in section III

CLASS NUMBER	NUMBER OF HERDS IN CLASS	SIZE OF HERDS	PERCENTAGE OF CONCENTRATE BOUGHT
35	13	Fewer than 20 cows	
36	4	20 to 39 cows	Under 50
37	2	40 or more cows	
38	13	Fewer than 20 cows	
39	19	20 to 39 cows	50 to 79
40	7	40 or more cows	
41	5	Fewer than 20 cows	
42	7	20 to 39 cows	80 to 100
43	16	40 or more cows	

2. CORRELATIONS OF THE PROPORTION OF CONCENTRATES PURCHASES TO OTHER FACTORS IN MILK PRODUCTION

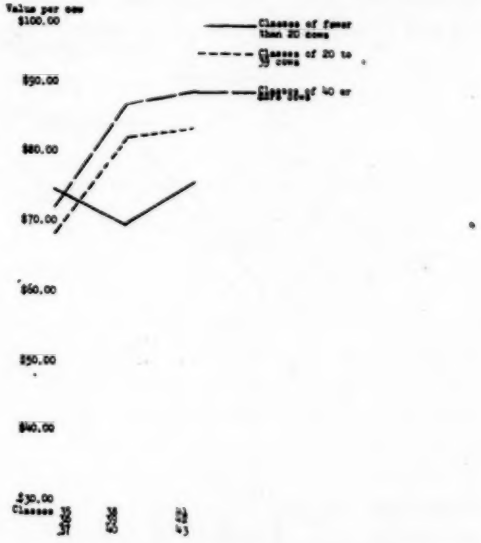
Effect of tenantry on the proportion of concentrates purchased

There are no tenant dairies of over 40 cows included in this study, but among those of fewer than 40 cows, it will be observed that, almost without exception, the proportion of tenant dairies to owner dairies decreases from class to class as the proportion of feed purchased to that grown increases.

In classes 35, 38 and 41 the proportion of tenants to owners ran, 5:8, 2:11, and 1:4. In classes 36, 39 and 42 it was 1:3, 4:15, and 1:6. Throughout this section of the study it is apparent that, the greater the farmer's incentive to saving and the necessity to economize in his expenditures the smaller the proportion of grain consumed by his cattle was he likely to purchase, even though this often resulted in expenditures so small and penurious as to impair the efficiency of the business. The better off the farmer financially, the more likely he was to feed heavily and spend liberally, and, up to a certain point, this greater liberality resulted in greater productivity and increased profit.

Value per cow

From graph IX it may be observed that in dairies of 20 or more cows there is a tendency for the dairies purchasing the larger proportions of their concentrates to be composed of more valuable cows than those which purchase less and grow more. However, the value per cow in dairies purchasing 80 per cent or more of their grain does not differ materially from that of those



GRAPH IX. CORRELATION OF VALUE PER COW TO PROPORTION OF GRAIN BOUGHT

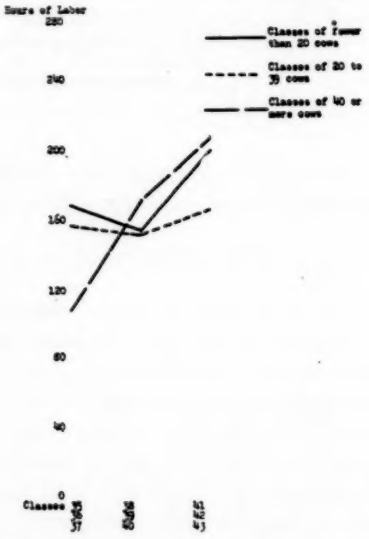
purchasing 50 per cent to 79 per cent. In the classes of fewer than 20 cows there is at first a slight increase in value then a practically equivalent decrease as the proportion of grain purchased increases.

In the case of the larger dairies, the farmers who were sufficiently progressive to keep the more valuable and more productive cows were either progressive enough to purchase a considerable amount of feed which would balance up the ration

provided partly by the home grown grains, or were simply liberal enough in their expenditures to purchase large amounts of grains.

Labor

The amount of labor used per cow shows a slight tendency to decrease as the proportion of feed purchased increases from 50 per cent to 80 per cent, then increases as a still greater pro-



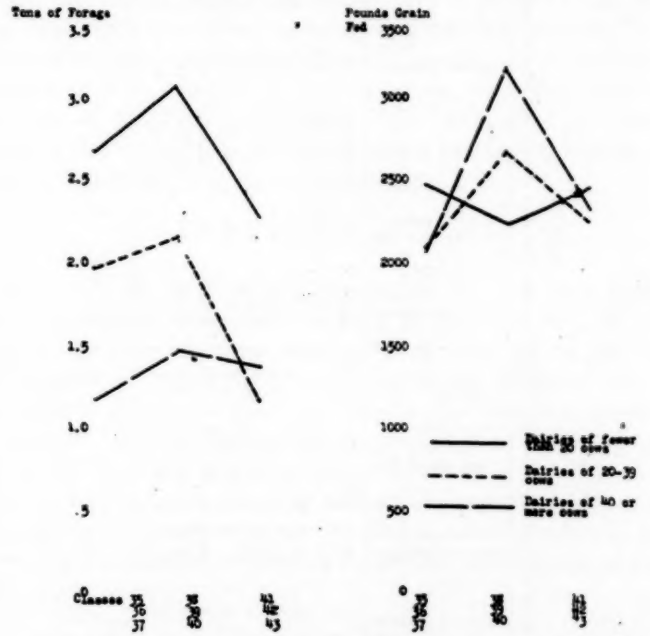
GRAPH X. CORRELATION OF LABOR TO PROPORTION OF GRAIN BOUGHT

portion is bought. In the case of the dairies of 40 or more cows a steady increase in the amount of labor used is shown. The refusal of the lower part of this curve to conform to the actions of the other two curves is attributable to the low average amount of labor used in class 37. This class contains but two dairies, one of which uses only 82 hours of labor per cow per year, which is far below the average amount used in dairies of this size.

This graph would suggest the possibility that dairies which use labor most efficiently, or at least most sparingly—and there is no reason to believe that the amounts of labor used in classes 38, 39 and 40 are insufficient,—are likely to purchase about the median proportions (50 per cent to 79 per cent) of grain.

Total amount of grain and forage fed

In graph XI it will be seen that the same liberality which causes the purchase of more grain, results at first in the feeding



GRAPH XI. CORRELATION OF FORAGE AND TOTAL POUNDS OF GRAIN FED TO PROPORTION OF GRAIN BOUGHT

of more forage simultaneously. But the dairies of fewer than 20 cows provide an exception to this insofar as grain is concerned. It might be expected from this, that the increase in the

TABLE 3

Section III. Correlations of proportion of concentrates purchased to the factors in milk production. Averages of classes 35 to 43

CLASS NUMBER	NUMBER OF HERDS IN CLASS	NUMBER OF OWNERS	NUMBER OF TENANTS	NUMBER OF COWS IN HERDS	VALUE PER COW	TONS OF FORAGE FED	POUNDS OF GRAIN FED	PERCENTAGE OF GRAIN BOUGHT	COST OF GRAIN	HOURS OF LABOR	QUARTS OF MILK	PROFIT OR LOSS PER COW	COST PER QUART	PRICE PER QUART	PROFIT OR LOSS PER QUART
35	13	8	5	11.2	$74.61	2.7	2,496	28	$36.20	171	1,854	−$54.23	$0.080	$0.048	−$0.033
36	4	3	1	26.9	68.75	2.0	2,123	30	29.04	158	2,401	−19.03	0.053	0.052	−0.001
37	2	2	0	50.5	72.50	1.2	2,085	44	26.61	110	2,371	−11.91	0.044	0.038	−0.006
38	13	11	2	13.7	70.00	3.1	2,277	61	32.09	157	2,096	−44.73	0.076	0.045	−0.031
39	19	15	4	26.2	83.42	2.2	2,724	65	41.19	154	2,683	−11.58	0.059	0.054	−0.005
40	7	7	0	65.0	87.86	1.5	3,181	66	43.14	175	3,177	− 8.78	0.054	0.049	−0.005
41	5	4	1	10.0	76.00	2.3	2,494	90	35.64	201	2,551	−20.54	0.062	0.052	−0.010
42	7	6	1	28.6	84.37	1.2	2,257	94	35.96	168	2,620	−10.79	0.056	0.051	−0.005
43	16	16	0	64.0	89.37	1.4	2,330	95	36.07	211	3,166	+28.76	0.054	0.062	+0.008

amounts of feeds used would continue as more and more grain is purchased, but in the dairies using 80 per cent or more of purchased grain there is a sharp falling off in the amounts both of grain and of concentrates used. The explanation of this is not difficult to find. Dairy farmers may be divided roughly into two more or less distinct groups: those whose aim is to consume chiefly home grown feeds partly or wholly unmarketable, and those who make no pretense at self-sufficiency but depend chiefly on such feed, especially grain, as they may be able to purchase. The latter type is to be found among the dairies purchasing 80 per cent or more of the grains they feed, and since these dairies must purchase practically all of the feeds they use, they are likely to use as little as will suffice. Because of the expense of transportation, etc., they generally use feeds of the highest nutritive value obtainable per unit of weight. Because of this the comparison in these tables on the basis of weight alone is somewhat unfair.

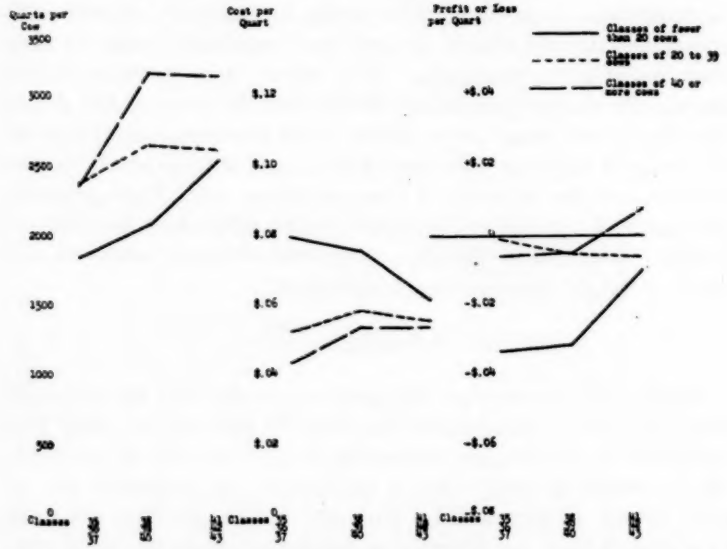
Production

Graph XII shows that the production per cow rises rapidly from the classes purchasing less than 50 per cent of their concentrates to the classes purchasing 50 per cent to 80 per cent. This increase in production is parallel to the increased use of feed shown in graph XI. But above the median point in purchase of feed, no decrease in production is to be found parallel to the decrease in feed used, as shown in graph XI. This is due to more efficient feeding and at the same time bears out the assumption mentioned above, that a better quality of feed is used by the dairies purchasing the largest proportions of their grain.

Cost of production

There is a tendency for the cost per quart of milk to increase slightly at first, then to decrease as still more feed is purchased. The dairies of few cows again provide an exception, for here the decrease is constant. This condition is incident to the condition

of diminishing returns which will be observed if the production curves in graph XII are compared to the curves for feeds in graph XI. As the group of dairies using 50 per cent to 79 per cent of purchased grain is passed all three curves show a decrease in cost per quart. This is due to the efficiency of the dairies which purchase most of their grain, as mentioned above.



GRAPH XII. CORRELATION OF PRODUCTION AND COST OF PRODUCTION TO PROPORTION OF GRAIN BOUGHT

Profit or loss per quart

In the dairies of fewer than 20 cows where an increase in general efficiency was observed to accompany an increase in the proportion of concentrates bought, but in no causative relation, the loss per quart decreases, at first slowly then rapidly as more feed is bought.

In dairies of more than 20 cows the variation in profit or loss was very slight except in class 43 where the profit was con-

siderably increased by the sale of "A," "nursery," and certified milk.

Thus, the variation in the profit or loss per quart is not apparently conditioned on the proportion of grain bought, as is supposed by many to be the case. The only way in which such a variation in profit could apparently exist would be for the farmers buying feeds to pay considerably more for them in the market than it would cost to grow the feeds. This condition does not appear to exist to any marked degree, for no uniform variation in profit or loss which could be explained by this assumption was observed in the data.

SUMMARY

1. It was observed that the greater the incentive to saving and economy in expenditures, the smaller the proportion of concentrates purchased. Thus, the tenant farmers, who may be assumed to have a greater incentive to saving, purchased a smaller proportion of their concentrates than the owners. Likewise, the owners of small dairies, whose economic status may be assumed to be inferior to that of the owners of large dairies, are to be found mostly in the groups buying less than 80 per cent of their grains. The dairies of medium size are mostly in the group buying the most grain.

2. In the classes purchasing from 50 per cent to 79 per cent of the grain they use, much more feed, both forage and grain, is fed than in those buying less than 50 per cent. This may be attibuted to a greater liberality in expenditures on the parts of the farmers as referred to above. But the dairies which purchase the greater proportion of grain use less feed than any of the other classes. This may be attributed to a higher quality of feed being used and to its more efficient use.

3. The dairies in the median group use labor most sparingly.

4. Production, cost of production and profit or loss per quart are influenced by the above three factors. The effects and counter tendencies among these and other factors are, however, such as to make it impossible to say that production, cost of production

or profit or loss per quart are affected by the proportion of feed purchased to that grown, in any other way.

APPENDIX A

A List of the Dairies Composing Classes 10 to 43 Inclusive

SECTION I

Herds composing classes 10 to 25

Class 10. Dairies of fewer than 20 cows, using less than 140 hours of labor per cow per year.

Herds 3, 22, 23, 42, 49, 54, 55.

Class 11. Dairies of 20 to 39 cows, using less than 140 hours of labor per cow per year.

Herds 8, 59, 60, 62, 65, 67, 69, 70, 87.

Class 12. Dairies of 40 or more cows, using less than 140 hours of labor per cow per year.

Herds 10, 40, 41, 45, 74, 76, 82, 84.

Class 13. Dairies of fewer than 20 cows, using 140 to 200 hours of labor per cow per year.

Herds 1, 2, 29, 35, 37, 48, 52, 56, 58, 78, 79.

Class 14. Dairies of 20 to 39 cows, using 140 to 200 hours of labor per cow per year.

Herds 13, 14, 24, 26, 34, 63, 66, 71, 72, 73.

Class 15. Dairies of 40 or more cows, using 140 to 200 hours of labor per cow per year.

Herds 16, 21, 25, 75, 85.

Class 16. Dairies of fewer than 20 cows, using more than 200 hours of labor per cow per year.

Herds 53, 57, 77.

Class 17. Dairies of 20 to 39 cows, using more than 200 hours of labor per cow per year.

Herds 61, 64.

Class 18. Dairies of 40 or more cows, using more than 200 hours of labor per cow per year.

Herds 36, 81, 83.

Class 19. Butter-making dairies, using less than 140 hours of labor per cow per year.

Herds 5, 6, 7, 28.

Class 20. Butter-making dairies, using 140 to 200 hours of labor per cow per year.

Herds 32, 47, 50, 51.

Class 21. Butter-making dairies, using more than 200 hours of labor per cow per year.

Herds 4, 30, 31, 39.

Class 22. Dairies producing "A," and "nursery" milk, using less than 140 hours of labor per cow per year.

Herds 15, 17, 20, 25.

Class 23. Dairies producing "A," and "nursery" milk, using 140 to 200 hours of labor per cow per year.

Herds 19, 33, 44.

Class 24. Dairies producing "A," and "nursery" milk, using more than 200 hours of labor per cow per year.

Herds 12, 27, 38, 46.

Class 25. Dairies producing "certified" milk.

Herds 11, 43, 86.

SECTION II

Classes 26 to 34

Class 26. Dairies of fewer than 20 cows, using less than 2000 pounds of concentrates per cow.

Herds 2, 3, 5, 23, 28, 30, 31, 32, 37, 48, 49, 52, 55, 58, 79.

Class 27. Dairies of 20 to 39 cows, using less than 2000 pounds of concentrates per cow.

Herds 6, 17, 18, 39, 60, 64, 66, 68, 69, 70.

Class 28. Dairies of 40 or more cows, using less than 2000 pounds of concentrates per cow.

Herds 12, 16, 20, 21, 74, 75, 76, 84.

Class 29. Dairies of fewer than 20 cows, using 2000 to 2999 pounds of concentrates per cow.

Herds 7, 22, 35, 42, 50, 54, 56.

Class 30. Dairies of 20 to 39 cows, using 2000 to 2999 pounds of concentrates per cow.

Herds 8, 14, 26, 33, 59, 62, 63, 71, 72, 73, 80.

Class 31. Dairies of 40 or more cows, using 2000 to 2999 pounds of concentrates per cow.

Herds 10, 25, 43, 45, 46, 81, 82, 83, 85, 86.

Class 32. Dairies of fewer than 20 cows, using 3000 pounds or more of concentrates per cow.

Herds 1, 4, 29, 47, 51, 53, 57, 77, 78.

Class 33. Dairies of 20 to 39 cows, using 3000 pounds or more of concentrates per cow.

Herds 13, 15, 24, 27, 34, 61, 65, 67, 87.

Class 34. Dairies of 40 or more cows, using 3000 pounds or more of concentrates per cow.

Herds 11, 19, 36, 38, 40, 41, 44.

SECTION III

Class 35. Dairies of fewer than 20 cows, buying less than 50 per cent of their concentrates.

Herds 2, 3, 4, 5, 7, 22, 29, 32, 37, 57, 58, 77, 78.

Class 36. Dairies of 20 to 39 cows, buying less than 50 per cent of their concentrates.

Herds 62, 63, 64, 71.

Class 37. Dairies of 40 or more cows, buying less than 50 per cent of their concentrates.

Herds 45, 76.

Class 38. Dairies of fewer than 20 cows, buying 50 per cent to 79 per cent of their concentrates.

Herds 1, 23, 30, 35, 42, 47, 48, 49, 50, 52, 54, 56, 79.

Class 39. Dairies of 20 to 39 cows, buying 50 per cent to 79 per cent of their concentrates.

Herds 6, 13, 14, 15, 17, 24, 27, 33, 34, 59, 60, 65, 66, 67, 68, 72, 73, 80, 87.

Class 40. Dairies of 40 or more cows, buying 50 per cent to 79 per cent of their concentrates.

Herds 11, 19, 25, 40, 41, 83, 85.

Class 41. Dairies of fewer than 20 cows, buying 80 per cent or more of their concentrates.

Herds 28, 31, 51, 53, 55.

Class 42. Dairies of 20 to 39 cows, buying 80 per cent or more of their concentrates.

Herds 8, 18, 26, 39, 61, 69, 70.

Class 43. Dairies of 40 or more cows, buying 80 per cent or more of their concentrates.

Herds 10, 12, 16, 20, 21, 36, 38, 43, 44, 46, 74, 75, 81, 82, 84, 86.

BREED AND SIZE OF COWS AS FACTORS AFFECTING THE ECONOMY OF MILK PRODUCTION

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In considering the relation of breed and size of cows as factors affecting the economy of milk production it is not always possible to draw sharp distinctions and to attribute any one phenomenon to either factor alone. Hence these factors are considered together.

The large cows of any breed have an advantage over the smaller cows in not requiring so much feed for maintenance per pound of live weight. This fundamental principle of animal nutrition was discovered only during the last century. The renowned French chemist Lavoisier was the first to solve the puzzle which had existed regarding the source of animal heat. He proved that this is due to the combustion of materials within the tissues of the body. In the process of combustion the oxygen inhaled unites with the materials in the tissues. This forms the only source of energy and heat production to the body. Many years later other scientists showed that the amount of heat produced and given off from the body is greater per pound of live weight in the case of small animals than with large animals of the same kind. It was further found that the amount of heat given off is in proportion to the body surface of the animal and not in proportion to its weight. Since small animals have a greater surface in proportion to their weight than large animals, there is a greater radiation of heat per pound of live weight in the case of the smaller animals.

A ratio has been worked out showing the relation between the maintenance requirements of animals of different weights. This ratio is based on the geometrical theorem that the surface of two solids of similar shape are to each other as the squares of the cube roots of their weights. Having given the maintenance requirements of a cow of known weight the requirements of any

other cow of known weight may be calculated. For example, the daily maintenance requirement of digestible true protein for a 1000-pound cow is shown in the table below to be 0.5 pound. The requirement of a 1500-pound cow which may be represented by x might then be computed as follows:

$$1000^{2/3} : 1500^{2/3} :: 0.5 : x$$

Solving the proportion

$$100 : 131 :: 0.5 : x$$
$$x = 0.655$$

The figure 0.655 agrees with that shown in the table as the protein requirements of a 1500-pound cow. Thus, instead of the

TABLE 1

Daily maintenance requirement for cows (1)

WEIGHT	DIGESTIBLE TRUE PROTEIN	THERMS NET ENERGY
pounds	*pounds*	
750	0.413	4.95
800	0.431	5.17
900	0.466	5.59
1,000	0.500	6.00
1,100	0.533	6.39
1,200	0.565	6.78
1,300	0.596	7.15
1,400	0.626	7.51
1,500	0.655	7.86

maintenance requirements of a 1500-pound cow being 50 per cent greater than those of a 1000-pound cow, as might be expected, they are in reality but 31 per cent greater in the case of protein, and as may be calculated from the table, but 32 per cent greater in the case of energy.

It has usually been assumed that dairy cows will consume an amount of feed, particularly roughage, in almost direct proportion to their live weights (2). Were this true the large cows would have a very great advantage over the small cows in the economy of production on account of their maintenance being proportionately less. It is shown by tables 2 and 3 that while

large cows do consume more feed than small cows, the amount of feed consumed per pound of live weight of the animals is greater in the case of the small cows than with the large ones.

TABLE 2

Records of cows entered in Wisconsin cow competition[*]

CLASS	NUMBER OF COWS	AVE. LIVE WEIGHT	MILK	SOLIDS	FAT	FEED UNITS
			Holsteins			
		pounds	*pounds*	*pounds*	*pounds*	
1,000 and less	16	927	13,192.7	1,589.6	456.93	7,905
1,001–1,100	21	1,081	14,141.7	1,689.1	483.15	7,543
1,101–1,200	42	1,170	14,089.5	1,683.6	480.73	7,650
1,201–1,300	25	1,274	15,616.5	1,865.6	529.27	8,145
1,301–1,400	26	1,377	16,441.7	1,845.1	527.86	7,950
1,401–1,500	10	1,475	15,359.9	1,875.0	544.71	8,180
Over 1,500	8	1,669	17,017.1	2,042.4	592.07	8,675
Average.....		1,225	14,712.3	1,833.2	505.32	7,890
			Guernseys			
800 and less	5	762	6,935.6	983.5	351.36	5,989
801– 900	32	863	7,579.4	1,073.8	384.24	6,109
901–1,000	56	962	8,623.0	1,208.8	427.633	6,394
1,001–1,100	29	1,068	9,165.4	1,270.3	444.794	6,739
1,001 and over	19	1,202	9,446.7	1,334.0	479.111	6,930
Average.....		987	8,548.9	1,199.7	425.55	6,458
			Jerseys			
800 and less	10	766	6,065.5	862.5	309.51	4,985
801– 900	34	866	7,031.8	970.2	360.87	5,614
901–1,000	21	945	7,180.3	1,038.4	375.99	5,666
1,001 and over	11	1,109	7,897.9	1,124.6	402.46	5,535
Average.....		909	7,063.0	997.17	364.31	5,534

[*] Table 2 was compiled by sorting according to live weight and breed the records of all cows for which live weights are given and which completed records in the Wisconsin cow competition as stated in Wisconsin Research Bulletin No. 26 (3). Table 3 was compiled from the data in table 2.

These facts hold true in a general way for all of the cows entered, but more particularly for the cows of the various weight classes within each of the breeds. From the lighter classes to

the heavier there was a remarkably uniform decrease in consumption of feed units per pound of live weight. There is some difference in this respect, however, between the three breeds. Selecting the 1001–1100-pound classes of the Holsteins and

TABLE 3

Number of feed units consumed per pound of live weight and pounds of product per 100 feed units of cows in Wisconsin cow competition

CLASS	NUMBER OF COWS	AVERAGE LIVE WEIGHT	FEED UNITS PER POUND LIVE WEIGHT	PRODUCT PER 100 FEED UNITS		
				Milk	Solids	Fat
Holsteins						
		pounds		*pounds*	*pounds*	*pounds*
1,000 and less	16	927.0	8.53	166.9	20.11	5.78
1,001–1,100	21	1,081.0	6.97	187.5	22.39	6.41
1,101–1,200	42	1,170.0	6.54	184.2	22.01	6.28
1,201–1,300	25	1,274.0	6.39	191.7	22.90	6.49
1,301–1,400	26	1,377.0	5.76	206.8	23.21	6.64
1,401–1,500	10	1,475.0	5.54	187.8	22.92	6.66
Over 1,500	8	1,669.0	5.19	196.1	23.54	6.82
Average.....		1225.0	6.44	186.5	23.24	6.40
Guernseys						
800 and less	5	762	7.86	115.8	16.42	5.87
801– 900	32	863	7.08	124.1	17.58	6.29
901–1,000	56	962	6.64	134.9	18.90	6.69
1,001–1,100	29	1,068	6.31	136.0	18.85	6 60
1,101 and over	19	1,202	5.76	136.3	19.25	6.91
Average.....		987	6.54	132.4	18.59	6.59
Jerseys						
800 and less	10	766	6.51	121.7	17.39	6.21
801– 900	34	866	6.48	125.3	17.28	6.42
901–1,000	21	945	5.99	126.7	18.32	6.63
1,001 and over	11	1,109	4.99	142.7	20.32	7.27
Average.....		909	6.09	127.6	18.02	6.58

Guernseys and the 1001 and over class of the Jerseys, which are no doubt the most comparable, it will be noted that the Holsteins consumed the most feed in proportion to weight, the Guernseys next and the Jerseys least.

Although the larger cows consumed less feed in proportion to size than the smaller ones they produced milk, total solids and butterfat with greater economy of feed. This is shown in table 3 and is illustrated graphically in figures 1, 2 and 3. While the economy of production does not increase uniformly with greater size of cows, there is a very significant increase in economy when all the classes of cows within each breed are considered.

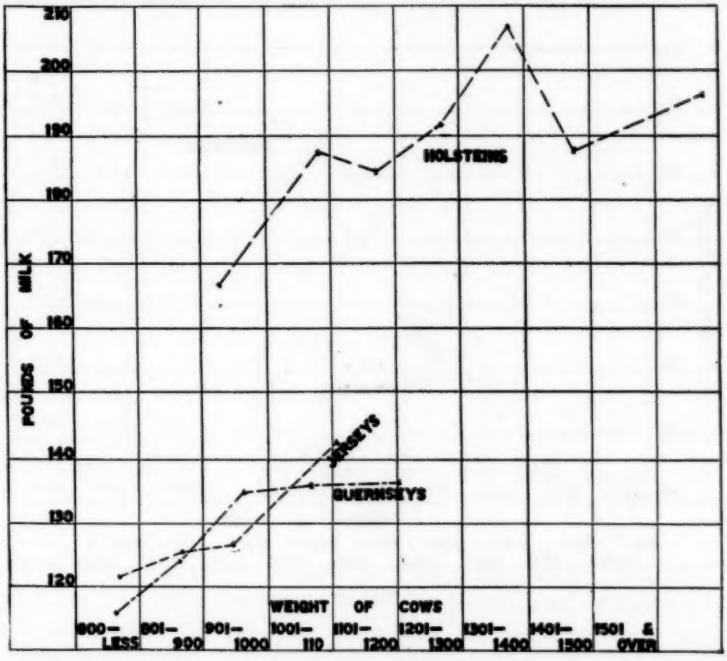

FIG. 1

In milk production those cows in the heaviest class of Holsteins returned 29.2 pounds more milk for each 100 feed units than did the cows in the lightest class. Similarly, the largest Guernseys returned 20.5 pounds more than the smallest while the heaviest cows of the Jersey breed were also much more efficient, returning 21 pounds more milk per 100 feed units than the lightest

class of Jerseys. In production of total solids a like relation holds true, there being a difference in economy of production in favor of the heaviest cows over the smallest to the extent of 3.43 pounds for the Holsteins, 2.83 pounds for the Guernseys and 3.02 pounds for the Jerseys.

In butterfat production there was, of course, a much smaller numerical difference, but a relationship similar to that of the two instances just mentioned. The largest Holstein and Guern-

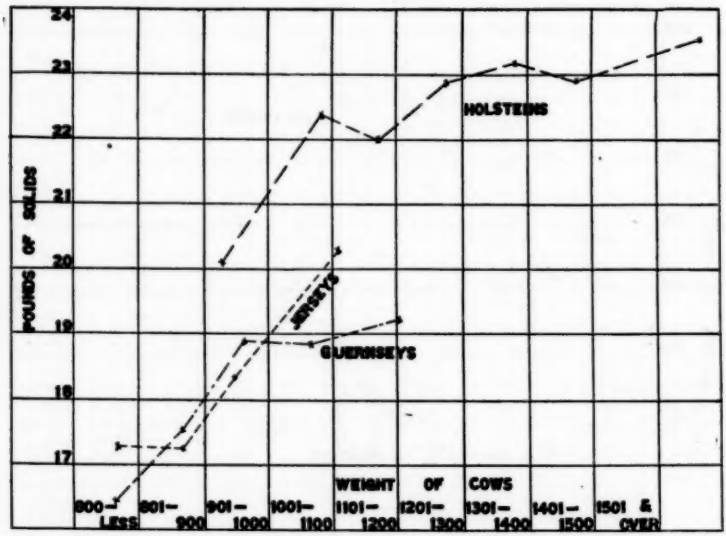

FIG. 2

sey cows produced 1.04 pounds more butterfat than the smallest cows of their respective breeds, while the largest Jerseys produced 1.06 pounds more.

Considering the average production of all the cows of each breed, as noted in table 3 it is shown that, as a whole, the 148 Holsteins produced milk and total solids much more economically from the standpoint of feed than the 141 Guernseys or the 76 Jerseys. This is a very important point commercially if

the milk were sold by weight without regard to test. The Holsteins produced 54.1 pounds more milk from each 100 feed units than did the Guernseys. At $3.00 per 100 pounds this would be worth $1.62. The 58.9 pounds of milk which the Holsteins produced in excess of that produced by the Jerseys would, at the same price, be worth $1.77. This, therefore, is a very important item to consider when selecting a breed of cows to furnish milk to a whole milk market.

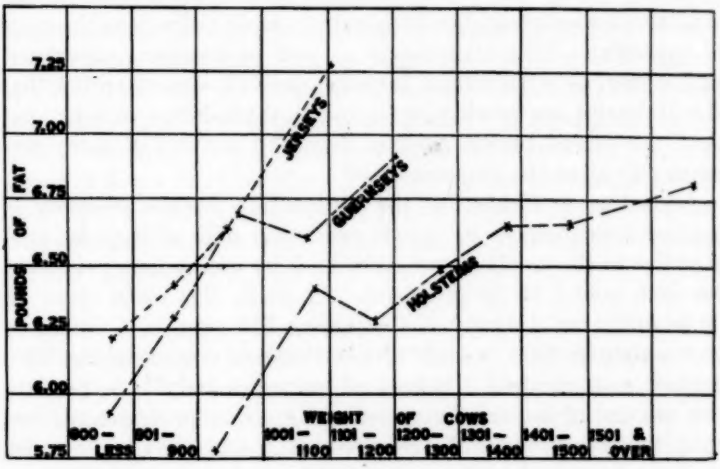

FIG. 3

Although total solids in milk are not marketed as such they form the valuable constituent of condensed and evaporated milk and milk powder. As indicated in this discussion the Holsteins produced milk solids much more efficiently than either the Guernseys or Jerseys. It was found by Eckles (4) in an investigation of the "Nutrients Required for Milk Production" that "the energy value of the milk solids is greater in proportion to the energy value of the feed required with the milk lower in fat. This indicates the production of rich milk requires an increase in feed in excess of the increase in energy value of the milk."

In butterfat production the order of economy of production by the different breeds is changed. The Guernseys were most economical, producing 0.01 pound more from each 100 feed units than the Jerseys and 0.19 pound more than the Holsteins. At $0.50 per pound for butterfat the more economical yield of the Guernseys would return $0.005 more for each 100 feed units than that of the Jerseys and $0.095 more than that of the Holsteins. This is a much smaller difference than in the case of the milk. However, the difference is great enough to be of considerable importance when the product is sold entirely on the basis of butterfat. This comparison as well as practical experience and numerous experimental investigations (4) demonstrated that the Holsteins are much more economical producers of milk, but that the Island breeds produce butterfat somewhat more economically than the Holsteins.

According to Eckles (4) the explanation for the economy of butterfat production by breeds producing milk of high fat content lies in the smaller amount of feed for maintenance required for each pound of fat produced. To make this point clear, let us assume that a Jersey cow weighing 750 pounds, a Guernsey cow weighing 1000 pounds and a Holstein cow weighing 1500 pounds each produce 1 pound of butterfat daily. To produce this amount of fat, the Jersey cow needs a smaller amount of feed than the others, since she requires much less for maintenance, as shown in table 1. After deducting the feed necessary for maintenance from the total feed consumed Eclkes found that the amount of energy required to produce a pound of fat was greater for the richer milk, but on account of smaller maintenance less total feed was required for each pound of fat produced in the high testing milk. On the other hand, the production of milk high in fat requires considerably more energy, since it contains a slightly higher percentage of total solids and more fat per pound than the low testing milk. The Holsteins thus have the advantage in economy of milk production.

It must not be concluded from the results of the Wisconsin competition here discussed that exactly the same relationships would be found to exist under different conditions. For ex-

ample, it was shown that the Holstein cows in this competition consumed more feed in proportion to live weight than Jerseys. This may be due to the fact that the Holsteins in this case were of much greater productive capacity than the Jerseys, the average production of butterfat not only being much greater, but there being no Holsteins which produced as little as the lowest producing Jerseys. Eckles (5) explains the great feed consumption of high producing cows by stating that the appetite of a cow is governed largely by the work she is doing, that is, the voracious appetite causing the consumption of great quantities of feed results from the production of large quantities of milk and is not the cause but the effect of the milk production. Assuming that this is true, it is entirely possible that high producing Jerseys would consume as much feed per pound of live weight as Holsteins of equal dairy ability. Thus the spread between the economy of milk production of the breeds might not be as great, while the difference in economy of fat production might be greater than is shown above.

CONCLUSIONS

The maintenance requirement of cows is directly proportionate to body surface and not to weight. The larger cows thus have a slight advantage in amount of feed required per 100 pounds of live weight. Large cows eat and produce more than small cows and are more efficient producers.

Of the cows entered in the Wisconsin cow competition, the Holsteins were the most efficient producers of milk and total solids. The Guernseys and Jerseys were about equally efficient as producers of butterfat, and both breeds were slightly more efficient in this respect than the Holstein.

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THE COLON-AEROGENES GROUP OF MILK

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Definite information concerning the significance of the colon-aerogenes group of bacteria in milk is rather obscure. The characteristic gas fermentation and acid production class such organisms as undesirable in the manufacture of dairy products. Their influence, however, upon the quality of market milk is less definite. According to Harding (5), the three essential elements determining the quality of milk are—food value, healthfulness, and cleanliness.

The colon-aerogenes group can effect the food value of milk only indirectly, in that through their undesirable fermentation they lessen the palatability of the commodity as a food. That the colon bacilli influence the healthfulness of milk is generally accepted, although very little direct proof is available. Such intestinal diseases as infantile diarrhoea, summer complaint and cholera infantum, commonly attributed to milk in warm weather, have long been associated with this group. More recent investigations along this line, however, tend to make one hesitate in placing so much emphasis upon such organisms as formerly. Until more authentic data is available to the contrary, it is no doubt wise that such organisms should be considered as a suspicious source of the non-specific intestinal disorders due to milk.

The colon family has long been considered of sanitary importance in milk. Numerous boards of health have adopted standards, based upon the colon content, for grading market milk. The usual assumption being that large numbers of colon indicate production under filthy conditions. Recent work, however, by Ayers, Cook and Clammer (2), indicate that large numbers of colon bacilli in milk represent growth due to holding at high temperature and not to initial contamination.

The purpose of this investigation was to study the relation of the colon-aerogenes group to cleanliness of milk production.

MARKET MILK ANALYSES

During the summer of 1917, 135 samples of market milk, representative for this community, were examined for their total bacterial content, colon-bacilli and sediment. The milk was obtained from fourteen different dairies in sterile pint milk bottles. All samples were packed in ice containers and brought to the laboratory where they were immediately examined. The total bacterial content was determined according to the standard methods. The colon group was estimated by inoculating bile lactose fermentation tubes with varying dilutions of milk and incubating at 37°C. for two days. The fermentation tube showing gas in the highest dilution indicated the total number of colon bacilli per cubic centimeter. That gas production in the highest dilution indicated B. coli was confirmed by the isolation of pure cultures of this group from all tubes examined.

The milk samples, grouped according to their colon content and the respective total bacterial count are tabulated in tables 1, 2 and 3.

The lowest colon count recorded was 2 per cubic centimeter while the highest was 10,000,000 per cubic centimeter. The average count for the 135 samples was 167,890 colon per cubic centimeter, and 10,567,290 total bacteria per cubic centimeter. According to table 2, 66.6 per cent of the samples have a colon count of 1000 or less per cubic centimeter, while 33.3 per cent show a count of over 1000 per cubic centimeter. These counts are considerably higher than those reported by Ayers, Cook and Clammer, who found from the analyses of 70 samples of milk the number of colon organisms ranged from 100 to 28,400 per cubic centimeter, while only one sample contained more than 2000 per cubic centimeter. Excluding this sample the average for the 31 samples was 648 colon per cubic centimeter. On the other hand, Kinyoun and Dieter (7) give results, which are quite comparable with those obtained from the present investigations. They found, from the analyses of 50 samples of market milk collected during February an average colon content of 19,420 per cubic centimeter, while the average of 48 samples of market

TABLE 1

The colon and total bacterial content of market milk

NUMBER OF SAMPLE	COLON PER CUBIC CENTIMETER	TOTAL NUMBER PER CUBIC CENTIMETER	NUMBER OF SAMPLE	COLON PER CUBIC CENTIMETER	TOTAL NUMBER PER CUBIC CENTIMETER	NUMBER OF SAMPLE	COLON PER CUBIC CENTIMETER	TOTAL NUMBER PER CUBIC CENTIMETER	NUMBER OF SAMPLE	COLON PER CUBIC CENTIMETER	TOTAL NUMBER PER CUBIC CENTIMETER	NUMBER OF SAMPLE	COLON PER CUBIC CENTIMETER	TOTAL NUMBER PER CUBIC CENTIMETER
68	2	20T	15	100	800T	21	500	75T	106	1,000	10M	116	10,000	3M
9	10	90T	17	100	2,750T	38	500	500T	110	1,000	280T	127	10,000	32M
10	10	150T	18	100	110T	54	500	300T	113	1,000	300T	128	10,000	25M
20	10	20T	19	100	24T	61	500	115T	114	1,000	600T	129	10,000	2M
28	10	25T	24	100	130T	64	500	9M	115	1,000	200T	132	10,000	470T
29	10	130T	25	100	200T	69	500	2,500T	120	1,000	25T	44	100,000	15M
35	10	20T	26	100	3,400T	94	500	7M	122	1,000	700T	72	100,000	7M
39	10	120T	27	100	75T	103	500	3M	125	1,000	260T	81	100,000	5M
63	10	80T	30	100	165T	109	500	130T	134	1,000	9M	107	100,000	18M
65	10	19T	31	100	60T	117	500	2M	4	10,000	1M	1	500,000	81M
79	10	30T	48	100	2M	119	500	200T	12	10,000	2,500T	2	500,000	5M
92	10	600T	49	100	2M	16	1,000	5M	32	10,000	1M	62	500,000	6M
93	10	400T	52	100	64T	22	1,000	900T	33	10,000	4M	76	500,000	66M
99	10	40T	66	100	24T	23	1,000	800T	36	10,000	10M	80	500,000	7M
100	10	65T	67	100	230T	34	1,000	150T	40	10,000	8M	83	500,000	75M
102	10	70T	77	100	150T	37	1,000	540T	41	10,000	10M	85	500,000	5M
104	10	200T	78	100	40T	42	1,000	5M	43	10,000	5M	90	500,000	16M
105	10	4M	95	100	150T	45	1,000	5M	50	10,000	2,500T	126	500,000	15M
108	10	130T	97	100	180T	46	1,000	5M	59	10,000	10M	135	500,000	309M
112	10	30T	98	100	2M	53	1,000	200T	70	10,000	400T	47	1,000,000	25M
3	100	2M	101	100	8M	55	1,000	60T	73	10,000	10M	51	1,000,000	8M
5	100	2,500T	111	100	130T	56	1,000	460T	74	10,000	1,800T	86	1,000,000	181M
6	100	1,200T	118	100	117T	57	1,000	122T	75	10,000	5M	91	1,000,000	26M
7	100	300T	121	100	2M	58	1,000	180T	84	10,000	16M	130	1,000,000	136M
8	100	900T	123	100	800T	60	1,000	85T	88	10,000	18M	131	1,000,000	20M
11	100	65T	124	100	250T	71	1,000	210T	89	10,000	4M	133	1,000,000	38M
13	100	250T	14	500	6M	87	1,000	10M	96	10,000	30M	82	10,000,000	36M

Note:—T = 1,000; M = 1,000,000.

Note:—T = 1,000; M = 1,000,000.

TABLE 2

A summary showing the samples of market milk grouped according to their colon count

	DILUTION												
	0	1	1/2	1/10	1/100	1/500	1/1000	1/10,000	1/50,000	1/100,000	1/500,000	1/M	1/10M
Number	0	0	1	19	33	12	25	23	0	4	10	7	1
Per cent	0	0	0.74	14	24.4	8.8	18.5	17.0	0	2.9	7.4	5.1	0.74

TABLE 3

Showing group correlation of total bacterial content and colon count in milk

	NUMBER PER CUBIC CENTIMETER										AVERAGE COUNT PER CUBIC CENTIMETER
Average colon	2	10	100	500	1,000	10,000	100,000	500,000	1,000,000	10,000,000	167,890,000
Average total	20,000	325,500	971,000	2,037,000	2,230,000	8,700,000	11,250,000	58,500,000	62,000,000	36,000,000	10,567,290

milk collected during August was 196,458 colon bacilli per cubic centimeter.

It is a generally accepted fact that while the bacterial content of milk is now universally used as a standard for judging the quality it is not a satisfactory index of sanitary production. It is more closely related to the care taken in the handling of the

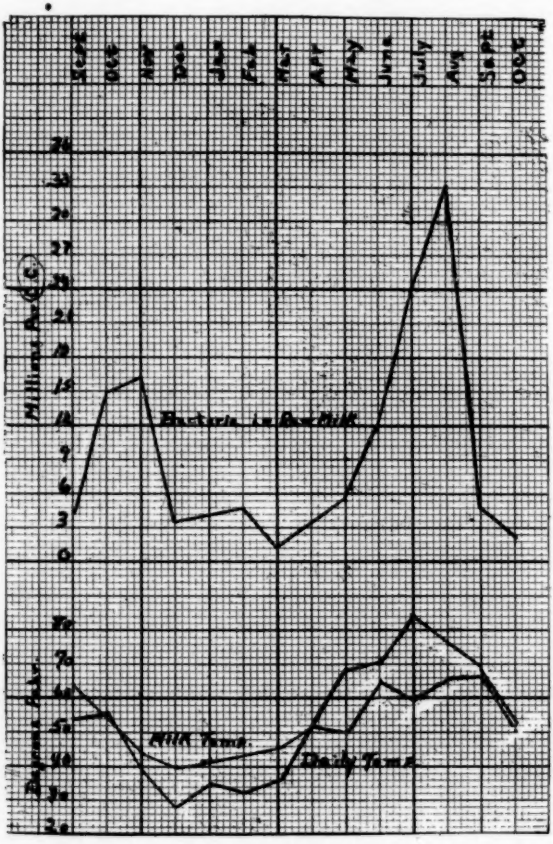

FIG. 1. CORRELATION OF TOTAL BACTERIA CONTENT OF MILK WITH TEMPERATURE

milk after production, than it is to the conditions under which the milk is produced. The temperature at which the milk is held, is one of the most important and influential factors governing the bacterial content of market milk. This is aptly illustrated in figure 1, the data of which is cited by Kinyoun and Dieter. That the increase in the bacterial content of the milk is due chiefly to temperature conditions is very apparent. The authors of the data, however, fail to attribute much importance to temperature.

In table 3 there will be observed condensed data demonstrating a direct relationship between the total bacterial content of milk and the colon count. The samples were grouped according to their colon content and the average recorded for the corresponding total bacterial count of each group. Hammer and Hauser (4), in a study of the market milk of Iowa, concluded that while, in many instances, the colon count could be correlated with the total bacterial content, it was not always so. It is apparent that there are times, when the relationship between the total bacterial count and colon content of milk will vary widely, but it appears that in the majority of instances a general average of market milk analyses demonstrates the two counts to be closely correlated.

Since the bacterial content of milk and temperature are directly related, and since the total count and the colon content are correlated, it follows that the temperature and the colon content of milk must therefore be associated. This shows that the high colon count does not indicate initial contamination, but represents improper care in the handling of the milk after production. More data, cited by Kinyoun and Dieter in figure 2, illustrate this point clearly.

While figure 2 indicates the relationship between total numbers and the colon content of milk, figure 1 establishes the correlation of temperature and total numbers. Therefore, the colon content of milk must also be directly influenced by the temperature.

In the present investigation it was impossible to indicate any correlation between temperature and the colon count of market

milk as the samples examined were collected during midsummer when little variation of temperature was noted.

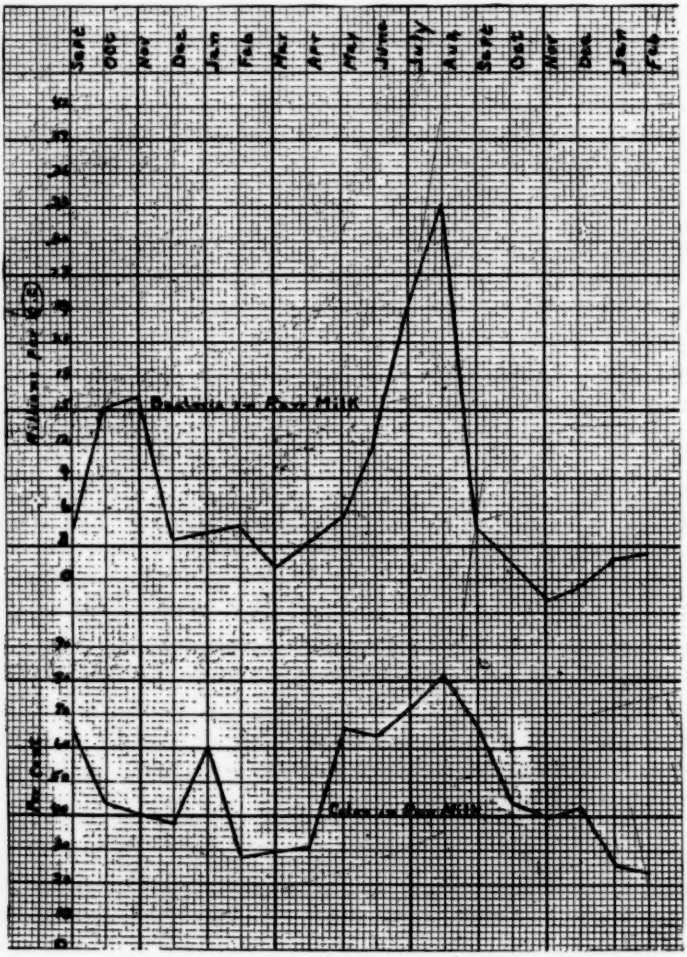

FIG. 2. CORRELATION OF TOTAL NUMBERS AND COLON CONTENT OF MILK

EFFECT OF TEMPERATURE

To study the effect of temperature upon the number of B. coli in milk, 59 samples of fresh milk were obtained from an average sanitary dairy. The milk was immediately examined and divided into two equal portions, one placed at 60°F. and the other at 70°F. After twenty-four hours the colon determination of each was made. The results are found in table 4.

TABLE 4

Showing effect of temperature upon colon content of milk

NUMBER COLI PER CUBIC CENTIMETER			NUMBER COLI PER CUBIC CENTIMETER		
Fresh milk.	Milk at 60°F.	Milk at 70°F.	Fresh milk.	Milk at 60°F.	Milk at 70°F.
1	100	50,000	10	10	100,000
1	2	100,000	10	10	100,000
1	100	100,000	10	100	1,000
1	10	50,000,000	10	10	100,000
1	100	10,000,000	10	10	100,000,000
2	100	100,000	10	100	50,000,000
2	10	50,000,000	10	10	100,000,000
2	10	1,000,000	10	10	500,000
2	10	1,000,000	10	500	100,000,000
2	10	1,000,000	10	100	100,000,000
2	100	500,000	10	100	10,000
2	2	100,000	10	100	100,000,000
2	10	500,000	10	10	500,000,000
2	2	500,000	10	0	1,000
2	10	10,000,000	10	100	500,000,000
2	100	10,000,000	100	10,000	1,000,000
2	100	500,000	100	10,000	100,000,000
2	100	1,000,000	100	10	500,000
2	100	1,000,000,000	100	10	10,000,000
10	10,000	100,000,000	100	1,000	1,000,000
10	10,000	100,000,000	100	100	1,000,000
10	1,000	100,000,000	100	1,000	1,000,000
10	10,000	1,000,000	100	100	50,000,000
10	500	100,000	100	100	10,000,000
10	100	50,000,000	100	1,000	100,000,000
10	1,000	50,000,000	100	100	50,000,000
10	100	1,000,000	100	100	100,000,000
10	10	1,000,000	500	500	10,000,000
10	100	100,000	1,000	100	50,000,000
10	100	10,000,000			
Average.....			52	964	60,762,000

The results are plainly evident. The average of the 59 samples indicates a total colon count of 52 per cubic centimeter in the original fresh milk; 964 per cubic centimeter in the same held at 60°F.; and over 60,000,000 per cubic centimeter for that portion held at 70°F. While these results are not surprising, they demonstrate that the number of B. coli in milk is greatly influenced by the temperature at which the milk is held. They further emphasize the need of care in handling milk after production, if the colon group is a factor in the healthfulness of milk. In table 5 the data obtained from these 59 samples of fresh milk, shows that 76.1 per cent of the samples had a colon count of 10 per cubic centimeter or less or 96.4 per cent of the samples had a colon content of not over 100 per cubic centimeter. The lowest number of B. coli recorded was 1 per cubic centimeter. While the highest was 1000 per cubic centimeter. The average count for the 59 samples was 52 colon per cubic centimeter. This data will certainly serve as a more accurate indicator of filth pollution than the results recorded from the market milk analyses.

TABLE 5

Showing the samples of fresh milk grouped according to their colon content

	NUMBER OF COLI PER CUBIC CENTIMETER							TOTAL
	0	1	2	10	100	500	1000	
Number	0	5	14	26	12	1	1	59
Per cent	0	8.4	23.7	44.0	20.3	1.7	1.7	100
Average number coli per cubic centimeter								52

THE COLON CONTENT OF COW FECES

Fifteen samples of fresh cow feces were examined for total colon content. The results are shown in table 6.

The lowest number per gram of feces was 100,000 and the largest number 10,000,000 per gram with an average of 1,883,333 per gram. According to Harding (5), in the poorest known commercial milk, the amount of recoverable foreign matter of

all kinds amounts to only 0.01 gram per liter. Reasoning on this basis it would mean that the number of colon organisms added to milk through initial contamination, would be less than 100 per cubic centimeter in the poorest quality of milk.

The sediment of the 135 samples of market milk, as determined by the Wizard Sediment Tester failed to reveal any correlation between total numbers and colon content. Likewise, the ex-

TABLE 6

Colon content of fresh cow feces

NUMBER OF SAMPLE	COLON PER GRAM	NUMBER OF SAMPLE	COLON PER GRAM
1	500,000	9	1,000,000
2	1,000,000	10	50,000
3	1,000,000	11	1,000,000
4	10,000	12	10,000,000
5	1,000,000	13	500,000
6	10,000,000	14	500,000
7	100,000	15	500,000
8	1,000,000		
Average			1,883,333

amination failed to indicate that there was an excess of foreign material which might account for such a large colon count.

The evidence appears sufficient to warrant the conclusion that the presence of the colon-aerogenes group in market milk can not be used as an index of initial pollution.

EFFECT OF MEDIA UPON THE ENUMERATION OF THE COLON GROUP

According to Jordan (6), bile lactose broth inhibits from one-third to one-half of the viable cells of B. coli, while Endo-agar compares favorably with lactose broth. Likewise, Obst (8) observed from the analyses of 191 samples of water, twice as many B. coli in lactose broth as in bile lactose.

To study the inhibitive effect of different selective media on the colon bacilli, the following media were used: bile lactose broth, lactose broth, asparagin broth and Endo broth.

Enumeration was made by gas production in fermentation tubes. It will be noticed that the asparagin and Endo media are made up as broth instead of agar. The asparagin media was made according to Ayers and Johnson (1) except the agar and litmus were omitted. Likewise, the Endo broth was prepared according to the standard methods omitting the agar. The period of incubation was two days, at 37°C.

The colon content of 48 samples of market milk as revealed by gas production in bile lactose and lactose broth is noted in table 7.

TABLE 7

A comparison of bile lactose and lactose broth for colon enumeration

SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER		SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER	
	Bile lactose	Lactose broth		Bile lactose	Lactose broth
1	100	1,000	25	1,000,000	100,000
2	1,000	100,000	26	10,000	50,000
3	100	100	27	1,000	10,000
4	10,000	100,000	28	1,000	500,000
5	1,000	10,000	29	100	1,000
6	10,000	1,000,000	30	1,000	1,000
7	100	1,000	31	100,000	100,000
8	10	10,000	32	1,000	10,000
9	100	1,000	33	10,000	50,000
10	500,000	500,000	34	100,000	500,000
11	10	100	35	100	500
12	100	1,000	36	50,000	100,000
13	10,000	500,000	37	1,000	10,000
14	1,000	10,000	38	50,000	100,000
15	10,000	500,000	39	1,000	1,000
16	10,000	100,000	40	2	10
17	10,000	10,000	41	10,000	100,000
18	1,000,000	500,000	42	50,000	1,000,000
19	100	10	43	100	100
20	500	500	44	10,000	100,000
21	500	1,000	45	10,000	50,000
22	1,000	10,000	46	100	10,000
23	500	10	47	500	1,000
24	10,000	50,000	48	50,000	100,000

A summary of the table indicates 36 samples, or 75 per cent of the 48 examined, gave a higher count in lactose broth; 4 samples, or 8.3 per cent gave a higher count in bile lactose, while 8, or 16.6 per cent of the samples had the same count in both media. The average count for bile lactose was 63,188 colon per cubic centimeter and for lactose broth 131,256 colon per cubic centimeter. An average of twice as many B. coli were noted in lactose broth as compared with bile lactose broth.

The number of B. coli were determined in 46 samples of market milk by bile lactose and asparagin broth fermentation tubes. The results are summarized in table 8.

TABLE 8

A comparison of bile lactose and asparagin broth for colon enumeration

SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER		SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER	
	Bile lactose	Asparagin broth		Bile lactose	Asparagin broth
1	10	100	24	1,000	10,000
2	100	2	25	10,000	1,000,000
3	100	10	26	100	1,000
4	100,000	2	27	10	1,000
5	2	10	28	100	1,000
6	2	10	29	1	10,000
7	10,000	10,000	30	500,000	100,000
8	1,000	1,000	31	10	100
9	1,000	100,000	32	100	1,000
10	1,000	10,000	33	1,000	50,000
11	10	100	34	10,000	500,000
12	10	10	35	10,000	10,000
13	2	2	36	10,000	10,000
14	2	1	37	100	100
15	2	2	38	500	10
16	2	2	39	500	500
17	2	2	40	1,000	10,000
18	2	1	41	500	1,000
19	1	1	42	10,000	10,000
20	100	1,000	43	1,000,000	1,000,000
21	1,000	1,000,000	44	10,000	50,000
22	100	1,000	45	1,000	100,000
23	10,000	100,000	46	100	500

The data demonstrate that 25, or 54.3 per cent of the samples gave a higher count in asparagin; 7, or 15.2 per cent had a higher count in bile lactose, while 14, or 30.4 per cent of the samples had same content. The average colon content as estimated by bile lactose broth was 36,749 per cubic centimeter, and for asparagin broth 88,901 colon per cubic centimeter. Asparagin broth gave on the average 2.4 times as many B. coli as bile lactose broth.

A comparison of bile lactose and Endo broth is indicated in table 9.

TABLE 9

A comparison of bile lactose and Endo broth for colon enumeration

SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER		SAMPLE NUMBER	NUMBER COLON PER CUBIC CENTIMETER	
	Bile lactose	Endo broth		Bile lactose	Endo broth
1	2	1	21	500	100
2	1	0	22	1,000	1,000
3	2	0	23	100,000	100,000
4	10,000	100	24	1,000	10,000
5	1,000	0	25	10,000	10,000
6	1,000	10	26	100,000	100,000
7	10	10	27	100	1,000
8	1,000	2	28	50,000	10,000
9	100	100	29	1,000	10,000
10	100	10	30	50,000	10,000
11	10	500	31	1,000	1,000
12	100	1,000	32	10,000	100,000
13	1,000	100,000	33	50,000	100,000
14	500	1,000	34	100	100
15	1,000	1,000	35	10,000	50,000
16	10,000	10,000	36	10,000	50,000
17	100	1,000	37	100	1,000
18	500	1,000	38	500	500
19	500	1,000	39	50,000	50,000
20	10	0			

Of the 39 samples of market milk examined, 15, or 38.4 per cent of the samples showed a higher count in Endo broth; 12, or 30.7 per cent in bile lactose broth, while the count in 12, or 30.7 per cent of the samples was the same. An average of the 39 samples gave a count of 12,108 colon per cubic centimeter with

bile lactose, and 18,498 per cubic centimeter by Endo broth. On an average 1.5 times as many colon grew in Endo broth as in bile lactose broth.

While identification of B. coli was not undertaken in all the samples, a fairly large per cent of the samples from each media were examined for colon verification. The samples which were examined for verification and the results obtained are listed in tables 10, 11, and 12.

TABLE 10

Colon verification from lactose broth fermentation tubes showing gas production

SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED	SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED
1	1,000	+	4A	50,000	+
3	100,000	+	5A	100,000	+
5	10,000	+	10A	1,000	+
6	50,000	+	4B	500	+
7	500,000	+	5B	500,000	+
8	500	+	3C	500,000	+
9	100,000	+	1C	10,000	+
10	10,000.	+	2C	500	−
11	100,000	+	1D	100,000	+
12	1,000	+	2D	10,000	+
13	10	+	3D	500,000	+
1A	1,000	+	4D	10	+

TABLE 11

Colon verification from asparagin broth fermentation tubes showing gas production

SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED	SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED
4A-1	1,000	+	1A-8	10,000	+
5A-2	500,000	+	2A-9	10,000	+
3A-3	500,000	+	3A-10	1,000,000	+
3A-4	500,000	+	4A-11	100	+
1A-5	50,000	+	4A-12	10,000	+
1A-6	50,000	+	5A-13	1,000,000	+
2A-7	10	+	9A-14	50,000	+

It will be observed that from lactose broth fermentation tubes there was only one case in which colon was not verified. Positive verification was obtained from all tubes of asparagin and

Endo broth examined. The bile lactose broth tubes in this series were not verified, in as much, as previous work in this laboratory as well as work of other investigators has shown that gas production in bile lactose is a reliable presumptive test for B. coli.

From these results it appears that the kind of media used for the enumeration of the colon group will greatly influence the quantitative estimation. The data indicated that asparagin media and lactose broth offer the least inhibitive action. Endo exerts an inhibitive power but not as great as lactose bile. Ayers and Johnson (1) compared bile lactose broth with asparagin agar

TABLE 12

Colon verification from Endo broth fermentation tubes showing gas production

SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED	SAMPLE NUMBER	DILUTION SHOWING GAS	COLI VERIFIED
4E-1	1,000	+	1E-10	1,000	+
5E-2	100,000	+	3E-11	100,000	+
6E-3	1,000	+	5E-12	10,000	+
7E-4	1,000	+	6E-13	10,000	+
9E-5	10,000	+	7E-14	100,000	+
10E-6	1,000	+	8E-15	1,000	+
12E-7	1,000	+	10E-16	10,000	+
13E-8	1,000	+	11E-17	10,000	+
15E-9	100	+	12E-18	1,000	+

for the enumeration of coli bacilli from ice cream and found that asparagin agar gave a higher colon count in 41 samples out of 43 examined. They also state that a much larger number of gas forming bacteria can be obtained in ice cream by the use of Endo agar than from asparagin agar. The fact that other organisms besides colon will grow on Endo which are difficult to differentiate, would exclude it, however, for reliable quantitative work.

EFFECT OF MEDIA ON COLON TYPES

To study the effect of different enrichment media upon the various types of the colon group, twenty-four to forty-eight hour broth cultures, representing B. coli communis, B. coli

TABLE 13

Effect of media on colon types

ORGANISM	NUMBER ON PLAIN AGAR	NUMBER FROM BILE LACTOSE BROTH	NUMBER FROM ENDO BROTH	NUMBER FROM ASPARAGIN BROTH	ORGANISM	NUMBER ON PLAIN AGAR	NUMBER FROM BILE LACTOSE BROTH	NUMBER FROM ENDO BROTH	NUMBER FROM ASPARAGIN BROTH
B. coli communis	10,000	500	1,000	10,000	B. lactis aerogenes	40,000	10,000	100,000	100,000
	4,000	500	500	1,000		10,000	10,000	10,000	10,000
	3,000	1,000	1,000	1,000		8,000	1,000	10,000	1,000
	1,000	500	1,000	1,000		10,000	1,000	10,000	10,000
	1,000	500	1,000	500		14,000	10,000	10,000	10,000
	5,000	500	1,000	10,000		15,000	10,000	10,000	1,000
	1,000	1,000	1,000	1,000		4,000	500	1,000	1,000
	50,000	10,000	1,000	1,000		20,000	50,000	1,000	1,000
	16,000	10,000	10,000	10,000		20,000	10,000	10,000	10,000
Average	10,000	2,700	1,950	3,950	Average	15,600	11,300	18,000	16,000
B. Coli communior	8,000	100	10,000	1,000	B. acidi lactici	4,000	1,000	1,000	500
	13,000	10,000	1,000	1,000		1,000	1,000	10,000	100
	30,000	10,000	1,000	10,000		1,000	100	1,000	1,000
	5,000	1,000	1,000	1,000		3,000	1,000	1,000	1,000
	3,000	500	10,000	1,000		3,000	1,000	1,000	1,000
	25,000	10,000	10,000	100,000		14,000	1,000	10,000	10,000
	7,000	1,000	1,000	1,000		4,000	1,000	1,000	1,000
	10,000	1,000	10,000	1,000		1,000	500	1,000	500
	14,000	1,000	1,000	10,000		10,000	1,000	10,000	1,000
Average	13,000	3,840	5,000	14,000	Average	4,500	844	4,000	1,800

communior, B. lactis-aerogenes, and B. acidi lactici were used. The same cultures were used throughout the experiment and all represented the fecal type of colon. A small portion of the culture was added to a sterile flask of physiologica[1] salt solution. The total number of each respective group was then obtained from each flask by plating on agar and inoculating bile lactose, Endo, and asparagin broth fermentation tubes. The counts on plain agar should represent fairly accurately the true number of colon bacilli present in each flask. The period of incubation was forty-eight hours at 37°C. The results obtained from the analyses of nine different samples of each culture are noted in table 13.

TABLE 14

Summarized data showing effect of media on colon types.

GROUP		PLAIN AGAR	BILE LACTOSE	ENDO BROTH	ASPARAGIN BROTH
B. coli-communis...	Average number	10,000	2,700	1,950	3,950
	Average per cent		63.0	80.5	60.5
B. coli-communior..	Average number	13,000	3,840	5,000	14,000
	Average per cent		70.4	61.5	0
B. lactis-aerogenes..	Average number	15,600	11,300	18,000	16,000
	Average per cent		27.4	0	0
B. acidi-lactici.....	Average number	4,500	844	4,000	1,800
	Average per cent		81.2	11.1	60.0
Average.....	Average number	10,775	4,671	7,237	8,937
	Average per cent		56.6	32.9	17.1

A summary of the table demonstrates B. coli communis to be inhibited more by all the media than the other types. Asparagin showing 60.5 per cent, bile, 63 per cent, and Endo, 80.5 per cent inhibition.

For B. coli communior asparagin exerted no checking influence, while Endo showed 61.5 per cent, and bile lactose 70.4 per cent inhibition.

B. lactis-aerogenes appears to be less influenced by media than the other types, asparagin and Endo showing no inhibition, while bile lactose decreased the count only 27.4 per cent.

B. acidi lactici is influenced by all three media. Endo decreases the group 11.1 per cent, asparagin, 60 per cent, and bile lactose, 81.2 per cent.

The results further demonstrate that asparagin exerts the greatest inhibitive action upon B. coli communis and B. acidi lactici and has no effect upon the other two members of the group. Endo broth exerts its greatest influence upon B. coli communis and B. coli communior; effects B. acidi lactici some and B. lactis aerogenes more. Bile exerts an inhibitive action on all types. An average of the counts for all types for each respective media, as shown in table 14 indicates that asparagin has an average inhibitive effect of 17.1 per cent, Endo, 32.9 per cent, and bile lactose, 56.6 per cent. These results compare fairly well with those obtained from the enumeration of the entire colon group from milk with the same media.

CLASSIFICATION OF THE COLON-AEROGENES GROUP OF MILK

The most important sources of original contamination of milk by colon organisms, are particles of manure and particles of feed falling in milk during production. The pollution of milk with manure should add a larger per cent of the fecal types of colon, while feed contamination would tend to increase the non fecal types. The method proposed by Clark and Lubs (3) for differentiating these two types, offers opportunity to study the original source of colon contamination in milk. Rogers, Clark and Davis (9) studied 125 colon cultures from milk and found 52 per cent of them to represent the fecal type and 48 per cent the non fecal type.

To study the type of colon bacilli occuring in milk in this locality, 590 cultures were isolated. Of the 590 cultures studied, 352 were obtained from bile lactose, 60 from Endo broth, 140 from asparagin broth, and 38 from lactose broth. Of the 352 cultures obtained from bile lactose, 70 were picked from Endo plates which had been streaked from the bile lactose tubes. All remaining cultures were isolated from plain agar plates, inoculated from the various fermentation tubes. All cultures were

TABLE 15

A summary of the colon cultures isolated from milk

		B. COLI COMMUNIS			B. COLI COMMUNIOR			B. LACTIS AEROGENES			B. ACIDI LACTICI			SUMMARY		
		Total	Reaction to mythyl red		Total	Reaction to methyl red		Total	Reaction to methyl red		Total	Reaction to methyl red		Total	Reaction to methyl red	
			Acid	Alkaline		Acid	Alkaline		Acid	Alkaline		Acid	Alkaline		Acid	Alkaline
Bile lactose to plain agar...	Number	1	1	0	165	133	22	108	73	35	8	8	0	282	215	67
	Per cent	0.35	100	0	58.5	73.8	26.1	38.2	67.6	32.4	2.8	100	0		76.2	23.7
Bile lactose to endo agar...	Number	0	0	0	31	23	8	37	24	13	2	2	0	70	49	21
	Per cent	0	0	0	44.2	76.1	25.8	52.8	64.8	35.1	2.8	100	0		70.0	30.0
Endo broth to plain agar...	Number	0	0	0	21	19	2	38	23	15	1	1	0	60	43	17
	Per cent	0	0	0	35.0	90.4	9.5	63.3	60.5	39.4	1.6	100	0		62.8	37.1
Asparagin broth to plain agar.....	Number	2	2	0	64	37	27	73	25	48	1	1	0	140	65	75
	Per cent	1.4	100	0	45.7	57.8	42.1	52.1	34.2	65.8	6.7	100	0		46.4	53.5
Lactose broth to plain agar	Number	0	0	0	14	7	7	23	11	12	1	1	0	38	19	19
	Per cent	0	0	0	36.8	50.0	50.0	60.6	47.8	52.1	2.6	100	0		50.0	50.0
Total.....	Number	3	3	0	295	219	76	279	156	123	13	13	0	590	391	199
	Per cent	0.5	100	0	50.0	74.5	25.7	47.2	55.5	44.4	2.2	100	0		66.2	33.7

tested for their purity and their morphology determined. Only those non spore producing, gram negative, lactose fermenting bacilli which failed to liquefy gelatin were considered as colon organisms. Gas production was observed in glucose, lactose, saccharose and dulcite sugars and the cultures grouped according to MacConkey s classification. They were classified according to origin by their reaction to methyl red. The summary of the findings are indicated in table 15.

B. coli communis represented 0.5 per cent of the total cultures isolated; B. coli communior, 50 per cent; B. lactis-aerogenes, 47.2 per cent, and B. acidi lactici, 2.2 per cent. That the colon group in milk indicate original fecal pollution is demonstrated by the fact that 66.2 per cent of the cultures isolated were fecal types while only 33.7 per cent were of the grain variety.

It is of interest to observe that of the 282 cultures obtained from bile lactose-plain agar, 76.2 per cent were fecal type; of the 70 cultures isolated from bile lactose Endo agar, 70 per cent were fecal origin; of the 43 cultures obtained Endo broth, 62.8 per cent were fecal origin; while of the 38 cultures isolated from lactose broth, only 50 per cent were fecal type, and of the 140 cultures obtained from asparagin broth, only 46.4 per cent represented fecal source.

CLASSIFICATION OF THE COLON-AEROGENES GROUP FROM COW FECES

Summarized data of 169 colon cultures isolated from cow feces are found in table 16.

Here 37.2 per cent of the cultures were grouped as B. coli communis, 45.5 per cent as B. coli communior, 9.4 per cent as B. lactis-aerogenes, 7.6 per cent as B. acidi lactici. The majority, or 82.7 per cent of the organisms were classed as belonging to the communis-communior group. As to source, 95.2 per cent of the cultures represented fecal type.

It would appear from these results that B. coli communis fails to develop to any extent in milk, or the methods for isolation in milk failed to favor their development. The inference might be

that large numbers of B. coli communis in milk indicate recent fecal pollution.

In this connection it is interesting to note, the fate of the grain type, during their passage through animals. Such material as forage and grain has a fairly large colon flora and the majority of these organisms are considered non-fecal types. The fact that the fecal strains predominate in fresh feces indicates that either the non-fecal types fail to survive during their passage through animals or there is a converting of types within the animal. However, most of the evidence relating to the interchangeability of types of the colon bacilli would tend to refute this latter point.

TABLE 16

A summary of the colon cultures isolated from fresh cow feces

MEDIA		B. COLI COMMUNIS			B. COLI COMMUNIOR			B. LACTIS-AEROGENES			B. ACIDI-LACTICI		
			Reaction to methyl red			Reaction to methyl red			Reaction to methyl red			Reaction to methyl red	
		Total	Acid	Alkaline	Total	Acid	Alkaline	Total	Acid	Alkaline	Total	Acid	Alkaline
Bile to agar.....	Number	63	61	2	77	75	2	16	15	1	13	10	3
	Per cent	37.2	96.8	3.1	45.5	97.4	2.5	9.4	93.7	6.2	7.6	76.9	3.1

SUMMARY AND CONCLUSION

The results obtained from these investigations indicate:

1. The colon-aerogenes family can not be used as an accurate indicator of sanitary milk production.

2. The number of colon organisms in milk is greatly influenced by temperature.

3. The total count in the market milk examined was closely correlated with the colon content.

4. The number of coli recorded from milk analysis will be influenced by the media employed.

5. An average of twice as many colon bacilli were observed from lactose broth as compared with bile lactose.

6. Asparagin broth, on an average gave 2.4 times the number of colon as bile lactose.

7. Endo broth gave on an average 1.5 times as many colon as bile lactose.

8. Asparagin exerted its greatest inhibitive action upon B. coli communis and B. acidi lactici, and failed to effect the other two members of the group.

9. Endo exerted its greatest influence upon B. coli communis and B. coli communior, and had no effect upon B. lactis aerogenes and B. acidi lactici.

10. Bile exhibited an inhibitory action upon all four members.

11. The original source of the colon family in milk is evidently fecal pollution for of 590 cultures isolated from milk, 66.2 per cent represented fecal origin.

12. Of 169 cultures isolated from fresh bovine feces, 95.2 per cent represented the fecal type of B. coli.

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THE TEMPERATURE OF SOLUTION OF BUTTER FAT IN VARIOUS REAGENTS

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The temperature at which a fat or an oil forms a homogeneous mixture with certain solvents forms one of its physical constants. The constant varies with the solvent used and with the conditions under which the determination is made. Most use has been made of the determination in the case of butter fat, since it forms a convenient method of detecting the substitution of margarine for butter. The reagent usually used has been glacial acetic acid, and in this case the determination has been known as the Valenta test, and the temperature observed as the Valenta number. The determination is made by heating equal volumes of the dry filtered fat and glacial acetic acid (usually 3 cc.) in a test tube until clear, stirring with a thermometer meanwhile. The mixture is then allowed to cool, continuing the stirring, and the temperature is noted at which turbidity first appears. In the case of butter fat, this is about 35°C. The constant varies within a few degrees with different samples of butter fat, but it varies still more with different samples of glacial acetic acid, owing to variations in strength, and this has prevented results obtained in one laboratory from being always comparable with those in another; in fact, even in the same laboratory it has been necessary, in order to obtain continuously identical results, to test a new consignment of acid against a sample of butter fat, the Valenta number of which was already known.

The reasons for the discrepancies in the Valenta test have been exhaustively investigated recently by Fryer and Weston (1) who have found that the two main causes are the hygroscopic nature of the acid and the presence of free acids in the fat. The latter reason does not much affect the test when used for butter fat, which is generally nearly neutral. They recommend that the reagent, in the form of the melted crystals, should be ad-

justed in strength by the addition of water so as to give a definite Valenta number with a standard oil, for which they suggest almond oil. The adjustment they made was to give a constant Valenta number of 80° to neutral almond oil. Acetic acid of this character gave a Valenta number of 38° with butter fat.

Acetic acid as a reagent has been modified also by Parker (2) who takes acetic acid of 99 per cent strength, adds to it 10 per cent of propionic or of butyric acid, and then 1 or 2 per cent of water until the reagent gives a turbidity temperature of 50° with fresh butter fat.

The only other reagent which has been used to any extent is alcohol. This was suggested first by Crismer (3) who used alcohol of 91 per cent strength and conducted the test in a sealed tube heated in an acid bath. The use of alcohol has been criticised by Fryer and Weston on account of its hygroscopic nature. They found that absolute alcohol when left in an unstoppered bottle over night absorbed sufficient moisture to vary a turbidity temperature several degrees. To avoid this they have suggested a modified reagent composed of equal volumes of alcohol (90 per cent) and amyl alcohol, with sufficient water added to give a turbidity temperature of 70° with almond oil. This reagent is not hygroscopic. As reagent bottles are not left unstoppered in practice, this criticism is not of moment, particularly as it has been found from tests made over a long period that alcohol kept in a small well-stoppered bottle gives constant results.

Absolute alcohol of over 99 per cent strength can be obtained commercially, and it appears simplest to use this reagent without modification and to carry out the process in the same manner as in the Valenta test. The result obtained may be called the Crismer number. For butter fat, the number is in most cases 53° to 54° although it may vary from 51° to 56°. Margarine gives quite distinct results from these. If made chiefly from beef fat, the Crismer number is over 65°; made from vegetable fats, the number is below 45°.

The number is affected by the presence of free fatty acid in the fat, being lowered about 1.5° in the case of butter for each per cent of acidity calculated as oleic acid. With fresh butter

and even with ordinary butters, it is hardly necessary to make any correction, but with old butters the acidity should be determined by titration with decinormal alkali. The percentage is multiplied by the factor 1.5 and the result is added to the observed temperature to give the corrected Crismer number.

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THE NUMERICAL INCREASE IN BACTERIAL COUNT OF MILK FROM THE PASTEURIZING VAT TO THE CONSUMER

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The tendency of the present day sanitarians to base the quality of milk on the basis of a numerical bacterial content has revolutionized the business of marketing milk, and has caused development and study of this problem to a degree unthought of twenty years ago.

Regardless of the virtues of such a method of rating, it is evident that unless some better system is devised, the numerical basis is to govern for some years to come. For the scope of dairy activities which this system governs, the reader is respectfully referred to the following table compiled from "Report of the Committee on Statistics on Milk and Cream Requirements of the Official Dairy Instructors Association," Journal of Dairy Science, vol. i, no. 1, May, 1917:

	POPULATION				
	5,000 to 25,000	25,000 to 100,000	100,000 to 500,000	Over 500,000	Total Cities
Number of regulations having a legal limit for bacteria in milk.....	95	66	24	4	189

From the above tabulation, it can be seen that a large amount of the milk handled in the United States is under the jurisdiction of the numerical rating, and that the number of dairies that face the problem of delivering milk at a low count is large.

In delivering the milk to the door of the consumer under a certain numerical limit, the dairyman faces a most perplexing problem, and one which demands constant study and attention, and which is probably one of the most difficult as well as discouraging phases of dairy science known. The least slip on the

part of the operator or his subordinates may cause an unaccountable rise in the bacterial count which may seriously affect his rating, and cost him the confidence of his customers. An unclean holding vat; a stray, partially cleaned bottle; dirty conducting pipes or dirty cooling sections; faulty refrigeration—these and numberless other small points may be the inadvertant cause of serious trouble and lost prestige in the local sphere of business.

As stated before, no attempt is made to discuss the "pros" and "cons" of the numerical rating for milk, but the compilations in this article are merely an impartial attempt to discover whether or not there should be a numerical increase in bacterial content under the usual conditions of handling milk, and if so, its extent. The figures here discussed are taken from the files of the City Health Department, Baltimore, Maryland, and embrace a total of twelve months, thus covering seasonal variations. This work consists of tracing the pasteurized product of 422 samples of some 30 dairies, embracing some of the most careful and conscientious dealers in the country, as well as some of the less progressive ones. The general routine of handling the city's milk is practically the same as that in all sections of the country, i.e., pasteurizing, bottling, storing, and delivering.

At this city, the system has been to collect samples before and after pasteurization, and to follow this up by collecting an original package the next morning as delivered to the consumer. These samples are brought to the city laboratory and tested for the numerical bacterial content, the technique employed being that of "Standard Methods," American Public Health Association. This procedure serves to check every detail of the handling of the product. It is regretted that even more samples were not carried completely through, but conditions such as laboratory contaminations and missing original packages caused the discarding of a great deal of data.

The results of these investigations as tabulated in table 1 reveal variations which are very interesting.

Each figure represents one sample carried through the complete process—a sample taken of the freshly pasteurized product,

and another of that day's lot taken at the door of the consumer the next day. Necessarily these figures are subject to the usual variation of milk counts, but it is believed that the general factor, or at least the proportionate trend of the curve is approximately correct.

TABLE 1

Per cent bacterial increase in samples taken on street over previous day's "afterpasteurization" count

	NUMBER SAMPLES	PERCENTAGE INCREASE																							DELIVERED AT HIGHER COUNT THAN RAW PRODUCT
		Under 50	50-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-1000	1000-1500	1500-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	8000-9000	9000-10,000	Over 10,000	Held to after past. figure	Less than past. product	
January	38	2	1	3	5	1	5	2	1	2		1	1	1	2		1							1	9	5
February	57	1	2	10	2	2	4	1	2	1		1	6	3	3	4	1		1	1	1			2	10	9
March	61	3	4	5	6	6	2	4	6	1	1		2	2	3	1	2						2	3	8	7
April	61		4	3	7	5		3	4	3		1	5	1	3		1			2	1		5	3	10	10
May	41		5	3	3	2				1	3	1	6		2	1							2	5	5	3
June	34	1	1	2	1	2	1	1	1	3	1		2	4				1		2	1		5	1	4	3
July	35	1	1	1	4	1	1	2	1	1	1	1	1	4	2	2	1						6		4	2
August	25	1	1	1			6	2	1				1		3	1	2						1		5	1
September	26	1		1		1	2	2	3			1	2	2	1	2	1	1			1		3		2	3
October	34	2	1	2	2	4	1		2	1		2	4		5		1	1					2		4	2
November	5							1					1											1	2	
December	4				1			1																	2	
Total	422	12	20	31	31	24	24	19	21	13	6	8	31	17	24	11	10	3	1	5	4		26	16	65	45

The percentage increase is calculated in terms of 100 per cent, i.e., if there are five times as many bacteria when delivered to the consumer as when the pasteurized product was taken, it is figured 500 per cent increase, etc. It will be noted that only 16 of the 422 samples were delivered at the same count as when taken from the cooling coils, or approximately but 4 per cent of the samples represented a "held" product, while 45 samples or over 10 per cent gave a higher count than the raw product before

pasteurization. Sixty-five samples or over 15 per cent were delivered to the consumer under the figure of the pasteurized sample of that lot. This is ascribed either to the inhibitory action of the refrigeration upon the germ content, thus adding to the efficiency of the pasteurization, or, possibly, to the inconsistency of the bacterial distribution in the samples. The margin of allowable laboratory error must also be considered in this connection. Despite the fact, however, that 15 per cent of the samples were delivered to the consumer below the figure of the pasteurized product, it is safe to assume that there is a definite

TABLE 2

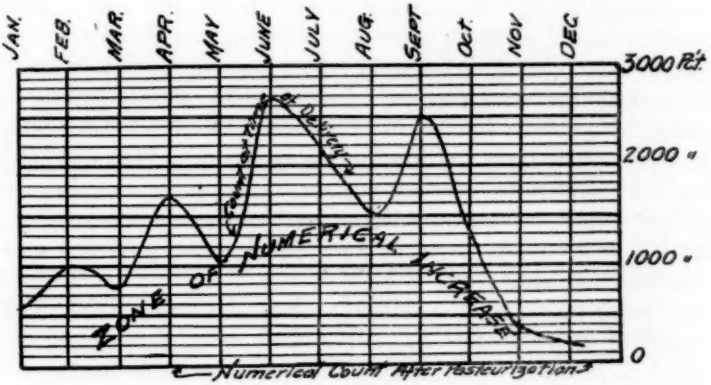
MONTH	NUMBER OF SAMPLES	PER CENT TOTAL INCREASE (NEAREST 500)	AVERAGE INCREASE NEAREST 50
January	38	19,000	550
February	57	57,500	1,000
March	61	44,500	750
April	61	103,000	1,700
May	41	42,000	1,000
June	34	92,000	2,700
July	35	80,000	2,300
August	25	36,000	1,450
September	26	64,500	2,500
October	34	44,500	1,300
November	5	1,500	300
December	4	800	200

increase, and to endeavor to ascertain a factor of increase, even if that factor must be rough.

On the basis of the tabulations in table 1, table 2 is compiled, and curve 1 is traced. From the general direction of the curve, it can be seen that, as would be assumed, the increase is proportionally larger during the summer months than during the winter. The reason for this is obvious, and strongly suggests the adoption of a sliding scale of rating for the hot months of the year if the dairyman's burden is to be lightened.

The extremely great variation as shown by these data leads to a question of cause, and in such a broad question, one can

assume several answers. Should the increase have been from but one dairy, naturally it would have been ascribed to carelessness or poor refrigeration, but where the increase has been so general, and has assumed such large figures, it suggests that there exists a considerable factor of reproduction of organisms that will grow on nutrient agar. The theory of efficient pasteurization if properly carried out, will cause the destruction of 99 per cent of the organic life in milk. The strongest and most resistant of the organisms survive, but if proper refrigeration and handling of the product is practiced, the counts should be held



CURVE I

constant, or nearly so. Then, wherein lies the great increase as shown in these figures? To the writer's mind, it is the result, principally, of faulty refrigeration. Even if the milk is capped in a stray unclean bottle which should unfortunately be selected for analysis, the chances are that if this bottle is iced at a temperature below that of reproduction, the increase will not be over a thousand or so organisms,—an equivalent of one colony on an agar plate of 1:1000 dilution, a case which is no way accountable for the extraordinary rate of increase as shown by the data.

As a means of arriving at some conclusion regarding this question of numerical increase, the following experiment was carried out, which shows, as nearly as possible, the relation of properly refrigerated original packages to original packages which were handled in the ordinary manner of delivery. It is also sometimes contended that clusters of bacteria are broken up by the jolting of delivery wagons during delivery, and in order to investigate this contention in a brief way, a slight addition was made to the experiment. These experiments were carried out in the following manner: The receiving tank of an automatic capper and filler was filled directly from the cooling coils with freshly pasteurized milk. Under the most careful technique, six samples were taken from this receptacle, and taken directly to the laboratory where analysis was made for the numerical bacterial content according to the technique of standard methods for same. Eighteen half pint bottles which had previously been sterilized in the laboratory, were filled from the filler and automatically capped; six of these samples were given contact refrigeration by icing them in an insulated collecting case, which, in turn, was placed in an insulated quart case box and again iced. This box, as well as the other 12 packages were placed in the refrigerator at the dairy which maintained an average of 44°F. All of these samples remained over night, a period of some twenty hours in the dairy refrigerator, and the next morning, the box and 6 of the packages which were iced in the customary manner of retailers—with a few small pieces of ice, were carried over a milk route in a four-wheeled wagon for a distance of some 8 miles, and a period on the road of about four hours. The other 6 packages were left at the dairy and were carried directly to the laboratory in an automobile, care being taken to reckon the time so as to have the delivery wagon and the samples from the dairy arrive at the laboratory as nearly as possible at the same time. The temperatures of these samples were taken and numerical counts run on them according to Standard Methods technique. In order to secure an unbiased result, the plating and counting in this experiment was done by a bacteriologist who was not familiar with the

object of the experiment. The results, as shown in table 3, were obtained by repeating this experiment.

TABLE 3

SERIES "A"—AVERAGE COUNT WHEN BOTTLED—8,500 BACTERIA PER CUBIC CENTIMETER			SERIES "B"—AVERAGE COUNT WHEN BOTTLED—5,000 BACTERIA PER CUBIC CENTIMETER		
Number	Temperature	Bacteria per cubic centimeters	Number	Temperature	Bacteria per cubic centimeters
I. Samples left in dairy					
1	51°	16,000	1	53°	2,400
2	54°	17,000	2	52°	2,600
3	54°	11,000	3	56°	2,000
4	56°	10,000	4	52°	2,000
5	55°	13,000	5	52°	3,500
			6	56°	3,000
Average when plated: temperature, 54°; bacteria, 13,500.			Average when plated: temperature, 53.5°; bacteria, 2,600.		
II. Samples carried over route in customary manner					
1	61°	16,000	1	58°	4,000
2	63°	25,000	2	58°	5,000
3	63°	18,000	3	54°	30,000
4	65°	10,000	4	58°	5,400
5	65°	19,000	5	58°	4,500
			6	64°	6,000
Average when plated: temperature, 63°; bacteria, 17,600.			Average when plated: temperature, 58°; bacteria, 9,100.		
III. Samples carried over route heavily iced					
1	42°	4,000	1	38°	3,400
2	41°	Contam.	2	38°	2,100
3	39°	5,000	3	37°	2,400
4	41°	13,000	4	38°	3,100
5	41°	6,000	5	37°	3,600
			6	38°	2,400
Average when plated: temperature, 41°; bacteria, 7,000.			Average when plated: temperature, 38°; bacteria. 2,800.		

In the series "A," the set 1, which was left at the dairy had a bacterial content of 30 per cent less than set 2, and 93 per cent

higher than set 3; set 3 was 93 per cent lower than set 1, and 151 per cent lower than set 2 which was carried the same distance, but which was not refrigerated as was set 3.

In the series "B," set 1, which was left at the dairy had a numerical count of 250 per cent lower than set 2 which was sent over the route, the content of set 1 being close enough to set 3 which was sent over the route heavily iced to call it the same. Set 3 had a bacterial content of 225 per cent lower than set 2, these two sets being subjected to the same disturbances of wagon jolting, etc.

The main difference which has the most direct bearing on the subject of this article is in the sets of heavily iced packages and those which were iced in the customary manner, both being sent over the same distance and, outside of refrigeration, being handled in an identical manner. In these instances, the heavily iced samples were delivered to the laboratory with a numerical count of 21 per cent and 78 per cent less than the count at the time of bottling, showing that when heavily refrigerated, milk packages can be at least "held" to the "after pasteurization" count. The increase of the samples which were carried over the route in the ordinary way over the heavily iced samples was 151 per cent and 225 per cent, respectively, while the tabulation of the year's work at Baltimore shows that 225 out of 422 cases, or a majority of instances, were delivered with an increase of under 500 per cent.

PRACTICAL DEDUCTIONS

1. From the results of this experiment, it seems safe to assume that the precautions generally observed by the dairyman in marketing milk are very inadequate. If the progressive dairyman is to meet the present-day standards of marketing milk from a numerical standpoint, he must master a detail which is generally well known, and as generally slighted refrigeration. From a business standpoint, to pasteurize milk properly and render void the good results of it by careless delivery methods, is folly. Regardless of the "safety" of pasteurized milk, it is a self-evident proposition that the grading and monetary return

from milk are not based on this standard—it is on the numbers of organisms which are counted by the bacteriologist on analysis.

2. That milk held to 40°F. from the period of pasteurization to the time of delivery, should not show an appreciable numerical increase in bacterial content.

3. Though the results of this experiment did not furnish a good check, it seems hardly probable that the jolting during the time of delivery has much bearing on the numerical count.

4. It is very probable that under the present day methods of delivery that the dairyman should look for around 500 per cent increase in the bacterial content above the figure of the after pasteurized product.

5. From the tabulations in this article, it can be seen that the business of marketing milk under the numerical limit law is not a matter of careless routine, but a science which demands the closest attention to every detail, and this method of grading has, as was previously stated, revolutionized the business of marketing milk. Not alone is it necessary to use ceaseless vigilance at the plant, but the up-to-date dealer must give a large part of his attention to his producers. A milk that is shipped to the plant with an extremely high bacterial content necessarily has a proportionately large number of the bacteria which survive pasteurization, and it is well nigh impossible to make a grade "A" pasteurized product out of a grade "C" raw milk.

As stated elsewhere, no attempt is made to discuss or criticise the numerical rating for milk grading, but it does seem that in such gradings, it would be only justice to the producer and seller of milk to adopt a sliding scale of bacterial count during the warm months, so as not to make a system which will automatically, year after year, change the grading of a conscientious dealer to a lower rating, despite precautions, and an inevitable attempt to control a factor which is uncontrollable, i.e., the elements.

THE HOUSEHOLD FOAM TEST FOR BUTTER AND OLEOMARGARINE

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One of the household tests for distinguishing between butter, and oleomargarine and renovated butter is the "foam test" described in Farmers' Bulletin No. 131, United States Department of Agriculture. Butter when heated boils quietly with the abundant production of foam, whereas oleomargarine and renovated butter sputter and do not produce so much foam. As no explanation for this difference, so far as we know, has ever been given, it was considered worth while to investigate the cause underlying this phenomenon. Further, with an explanation of the factors involved a more intelligent application and interpretation of the test is possible.

The possibility that the foaming of butter might be caused by some volatile compounds other than water was first considered, but was soon eliminated in the following manner:

The butter was warmed to 60°C., the butter fat decanted off and filtered, and the brine saved. The butter fat when heated did not foam, nor did it foam when water was carefully emulsified in it. It sputtered like an oleomargarine. The brine with the curd was diluted and boiled for several hours. On adding this boiled brine to the butter fat, mixing well, and then heating, an abundant foam was produced the same as with the original sample of butter.

Moreover, when the brine from butter was added to olive oil, and to oleo oil, and these oils then heated, the same volumes of foam were produced as in the case of butter. The difference in foaming between butter and oleomargarine and renovated butter must, therefore, be independent of the properties of these fats, but dependent upon the properties of the brine.

Surface tension suggested itself as a possible basis for explaining the "foam test." However, as stated above, both butter fat and oleo oil foamed equally well when mixed with the brine from butter and then heated. Therefore, a difference in the surface tension of these two fats cannot be the explanation for the difference in the foaming of butter and oleomargarine.

The surface tension of the brine itself cannot have a direct effect for the fat is the continuous phase under the conditions of the test. The brine could influence the surface tension of the fats by furnishing some fat soluble compounds; however, when the brine from butter was carefully filtered to remove the curd, and then added to the butter fat, it did not produce the foam. Therefore we must conclude that the explanation does not lie in surface tension, but rather in the properties of the curd.

In examining the brine from butter and from oleomargarine and renovated butter we find that the curd in the butter brine is finely divided, whereas the curd in the oleomargarine brine and renovated butter brine is coarser and has a tendency to aggregate on heating. The explanation of the difference in foaming is found in this fact. The small particles of curd in butter, holding small amounts of water in suspension in the molten fat, form centers for small volumes of steam. These small volumes of steam rise slowly to the surface and therefore do not burst. Thus an abundant foam is produced. In the case of oleomargarine and renovated butter the curd particles are larger and on heating they aggregate and the water immediately collects in larger droplets. The resulting sputtering is caused by the partial superheating of the water, large volumes of steam forming ,which then pass off violently allowing no foam to form.

This was demonstrated as follows: Casein was dissolved in dilute NaOH and the solution emulsified with fat (fat that did not foam). The NaOH was neutralized with dilute HCl. On heating this fat, foam was produced. The curd precipitated in this way is not quite so fine as that in the brine from butter and it has a tendency to aggregate, so the foaming was not quite so good as with butter.

According to the explanation advanced above, anything in the fat that will hold water and keep it from gathering in large droplets, should cause foaming. This was found to be the case. Filter paper, macerated to a pulp with water will cause foaming when incorporated into butter fat, olive oil, or oleo oil. Crystalline copper sulphate finely ground and incorporated with the fat also causes foaming.

Since the foaming does not depend upon the nature of the fat but upon the fineness of the curd or any other substance that is capable of holding water, it seemed possible that certain brands of "butter substitutes" should yield an abundant foam. This was found to be the case in the "butter substitute" made from the meat of coconuts (Troco). The finely devided tissues keep the small particles of water in suspension in the molten fat, and foaming results.

CONCLUSIONS

1. Fats will foam if the water that they contain is held finely divided in suspension; they sputter if the water gathers in droplets.
2. The curd in butter is finely divided and holds small particles of water in suspension; therefore butter foams.
3. The curd in oleomargarine and renovated butter is coarse and allows the water to gather in droplets; therefore oleomargarine and renovated butter sputter.
4. Certain "butter substitutes" that contain finely divided substances capable of holding water may foam as well as butter.

ABSTRACTS AND REVIEWS OF DAIRY LITERATURE

MILK AS A GALACTAGOGUE[1]

A paper by Dr. Chas. H. Duncan,[2] followed by several inquiries regarding the correctness of the claims made by its author as to value of injecting "each cow with a half ounce or more of her own milk on the third, fifth and tenth day after delivery" in order "to insure her doing her duty toward supplying milk," was made the basis for the experiments reported.

The method used by Palmer and Eckles for attacking the question whether milk itself can act as a galactagogue was to inject the milk of a fresh, heavy milking cow into the body of another cow of the same breed, whose milk production had also been heavy when fresh but which had decreased greatly due to a more advanced state of lactation.

Two such experiments were performed in which 20 cc. of milk from a fresh cow were injected subcutaneously into each shoulder of a cow advanced in lactation, injections being made on three alternate days. Careful records were kept of the daily milk flow prior to, during and following the injections. The results were entirely negative.

A third experiment was performed on one of the two cows into which injections were made, in which the immediate stimulating effect of the injected milk was tested. This was done by milking the cows as dry as possible, making the injection and repeating the milking after one hour. The results were compared with a similar procedure carried out on the preceding day except that no milk was injected into the cow. Negative results were secured in the experiment.

The conclusions is drawn that milk itself does not appear to be a galatagogue. The question is also raised why the galactagogue powers of milk, if such exist, should not be exerted while the milk is still in the mammary gland as well as after the milk is withdrawn and injected into another part of the body.—L. S. P.

[1] Abstract of an article by L. S. Palmer and C. H. Eckles, on Milk as a Galactagogue, in New York Medical Journal, cviii, pp. 375-376, 1918.

[2] Chas. H. Duncan. A New and Powerful Galactagogue, New York Medical Journal, cv. pp. 22-23, 1917.

DAIRY NOTES

Fred Silver Putney, professor of experimental dairy husbandry at the Pennsylvania State College, and well known among dairy professors and investigators throughout the United States, died of pneumonia at his home in State College, Pennsylvania, October 5, 1918.

Always interested in livestock problems, in recent years he has devoted his energies to teaching and fundamental research along the lines of animal nutrition. Dairy cattle feeding problems have been his special interest and his work along those lines is well known. He is a co-author with Dr. C. W. Larson of the textbook and general reference work, "Dairy Cattle Feeding and Management," and in conjunction with Dr. H. P. Armsby, of the bulletin, "Computation of Dairy Rations," in addition to numerous papers on dairy management and nutrition.

Professor Putney was born in Hopkinton, New Hampshire, November 10, 1881. He was graduated from the Concord High School in 1901 and received the B.S. degree from the New Hamphsire State College in 1905. In 1908 the Pennsylvania State College conferred upon him the degree of Master of Science, and he had completed recently the requirements for his doctorate degree at the University of Wisconsin.

Professor Putney first went to the Pennsylvania State College in 1906 where he worked with Dr. H. P. Armsby as an assistant in animal nutrition and general experimental work until 1908. That year he became assistant to Dean F. B. Mumford of the College of Agriculture, University of Missouri, at which institution he continued his studies in nutrition towards a doctorate degree. From Missouri he went to the Rhode Island State College as professor of animal husbandry and head of the department, and he remained at that institution for several years. In 1913 he returned to the Pennsylvania State College as assistant professor of dairy husbandry, and later became professor of experimental dairy husbandry.

For the past year, Professor Putney has been on leave of absence for advanced study in animal nutrition. This time he spent at the University of Wisconsin and had just completed the requirements for his doctorate degree. Professor Putney married Miss Bertha Bond of Urbana, Illinois, September 2, 1911, and they have one daughter, Ellen Ayers Putney, who was born July 6, 1917. Professor Putney

was a member of the American Association for the Advancement of Science, the Dairy Science Association, Alpha Zeta, Theta Chi, Acacia and the Order of Free and Accepted Masons. Just in his prime and in the fullness of his powers, the loss of Professor Putney will be keenly felt by his wide circle of friends and associates in dairy work. He had that rare combination of practical common sense combined with research ability which enabled him to keep a proper balance in all problems of a research nature. By his death, science has lost a well trained and efficient worker.—H. P. DAVIS.

Prof. H. F. Judkins, of the Connecticut Agricultural College, has recently accepted a position as associate professor in dairying at the Iowa State College. Professor Judkins was graduated from the New Hampshire College a year or two previous to his affiliation with the Connecticut College in 1913. His specialty is dairy manufactures and market milk.

Mr. W. A. Rhea recently resigned his position as head of the department of dairy husbandry of West Virginia University to become extension dairyman at the Connecticut Agricultural College. While a student at the University of Missouri, from which he received his bachelor's degree, Mr. Rhea attained prominence in judging dairy cattle. Later he attended Cornell University, receiving an advanced degree from that institution. Mr. Karl B. Musser, whose position was filled by Mr. Rhea, has taken charge of the dairy extension work in the state of Washington.

Prof. William M. Rider has recently accepted the appointment of director of extension service of the Holstein-Friesian Association of America, and will be located at the secretary's office at Brattleboro, Vermont. Professor Rider, at the time of his appointment was professor of animal husbandry and dairying at Syracuse University, Syracuse, New York, and has served in that capacity since 1915. Professor Rider took up his work at Syracuse in the fall of 1913, and taught during the college year of 1913–14, also superintending the University Farm. He was retained at Syracuse for the college year 1914–15, and during that period raised to full professorship and occupied the summer of 1915 in work on a master's degree in dairying at the University of Wisconsin at Madison.